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ABSTRACT

Project CLUE (Computer Learning Under Evaluation) was an extensive review of the state of the art of the instructional uses of computers. Students, laymen, administrators and teachers will find the first volume of the two volume final report directed to their needs. The introduction discusses the scope of computer uses considered and a timetable of project activities. Next offered is an overview of computer usage, including history, current aspects, and future trends, and guidelines for using the computer. Appendixes provide a guide to information sources, descriptions of representative projects, samples of instructional programs, a definition of the domain of Project CLUE, and a glossary. Volume II, directed toward computer scientists and researchers, contains six position statements on: operations and costs, computer-based learning materials, programing languages, evaluation of materials and strategy, research on instruction and learning, and documentation and distribution of materials. These statements are generated from literature and experts in the various fields. Bibliographies provide sources of statements and dissemination activities, list other projects contacted, suggest activities for professionals, and offer notes on computer system design for instructional uses. (Author/PB)

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Final Report

Project No. 8-0509
Contract No. OEC-5-9-32-509-0032

AN EVALUATIVE REVIEW OF USES OF COMPUTERS IN INSTRUCTION

Project CLUE (Computer Learning Under Evaluation)

Karl L. Zinn, Project Director

University of Michigan

Ann Arbor, Michigan

December 1970

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Project CLUE December 1970

1. INTRODUCTION

A. Scope of Computer Use in this Report

In innovative schools throughout North America, learners are using the computer to drill second language vocabulary, practice problem solving in algebra, simulate a national economy, model a theory about inheritance of traits, and retrieve information about films and other learning resources relevant to an individual program of study. Researchers are using the computer to administer complicated experiments, record and analyze data, build models of student learning and performance, and reduce the limitations on communication between man and machine. Project CLUE (Computer Learning Under Evaluation) has considered the use of computers for instruction, first, as a tool for instruction and, second, for research on learning and teaching.

Administrative uses of the computer for record keeping, scheduling, resource allocation, and data processing were not included in survey and review activities and are mentioned only incidentally. Although these administrative uses are extremely important to educators, critical review of this area was not as urgent as for the instructional domain. In particular attention has been given to the "conversational tutorial" uses of computing which are the subject of some controversy.

Interactive uses of the computer with the user "on-line" (directly connected) are often quite costly to implement at their present stage of development and occasionally the same function can be served just as effectively and less expensively "off-line" (without direct connection). The scope of Project CLUE includes all uses of the computer for instruction, whether the student waits one second or 24 hours for a reply. Some systems are arranged to provide results in from one to 30 minutes from a "remote job entry" terminal. The user does not have to carry his punched cards to the computer center but is able to interact with the machine using a card reader and printer located for his convenience.

The uses of the computer as an instructional aid have been represented by various initials including CAI, CBI, CMI, CAL, CAE, and many others. These labels tend to become associated for some persons with particular uses of computers or university projects or computer manufacturers. As a result any single name can mean different things to different readers.

"Computer-assisted" or "computer-aided instruction" (CAI) is now the most commonly used acronym. If the computer's role is to assist the teacher in managing instruction by handling performance records and curriculum files, the label is "computer-managed instruction" (CMI). However, many projects and manufacturers use variations of these two labels.

Authors of Project CLUE interpretations have avoided acronyms. When the CAI label is used it refers to a narrow definition of computer use, e.g., drill and tutorial activity. More comprehensive labels are intended to suggest a broad range: "computer-based learning activity," or the "computer as a learning tool," or "interactive uses in instruction." These phrases emphasize the learning process as much as a highly controlled instruction process, and the extension of the intellectual capabilities of the user as much as the testing of his factual knowledge.

In the next few paragraphs the domain of Project CLUE is summarized in terms of the manner of computer use as listed in Figure 1.1 (see also Appendix D).

Instruction and the learning process. The most visible use of computers in instruction is to provide direct assistance for learners or trainees, or for teachers, administrators, educational technologists and others who may wish to help learners. Any of these persons may pursue computer-related work individually at a user station or in groups of various sizes, directly connected to a computer (on-line) or not connected (off-line), with real or hypothetical computers, and so forth. Some typical subdivisions for this category of use are given in the first part of Figure 1.1.

Management of instructional resources and processes. Essentially clerical assistance can be important. Although uses in this category initially were considered to be aids to teachers and others concerned with supervising the instructional process, information and assistance can be provided to students directly without intervention of adult teachers and managers.

Within the various files for management of instructional resources and processes, the essential information is about student performance, learning materials, desired outcomes, job opportunities and student interests. The user would be able to compare his own performance, interests and goals with those of other students. After analyzing his performance, the student should be able to move into the materials file to find suitable help and then continue this self-directed activity by exploring the job opportunity or interest file.

Preparation and display of materials. Computers can be used to assemble individualized text and problems well in advance of their use by learners; materials then can be distributed by the most economical means. Generation of materials in "real time," that is, as needed by a student in a seminar or by a teacher during a lecture, is impressive but usually not necessary. Figure 1.1 includes some interesting subcategories of preparation and display: generating films, testing text materials, editing and analyzing texts, and representing knowledge by information structures.

INSTRUCTION AND LEARNING PROCESS

Drill
Skills practice
Author-controlled tutorial
Testing and diagnosis
Dialogue tutorial
Simulation
Gaming
Information retrieval and processing
Computation
Problem solving
Model construction (procedural)
Display construction (graphic)

MANAGEMENT OF INSTRUCTIONAL RESOURCES AND PROCESSES

Student records: selection and summarization
Materials files: retrieval via descriptors
Desired outcomes, job opportunities, interests, etc.

PREPARATION AND DISPLAY OF MATERIALS

Procedures for generating films, graphs, etc.
Laboratory for developing and testing text and graphic materials
Procedures for generating of text on an individual basis
Procedures for automatically editing and analyzing text materials for new uses
Information structures for representing knowledge, objectives and materials

OTHER USES

Educational administration: accounting, scheduling, planning, etc.
Educational research: institutional, sociological, psychological, etc.
Applied uses: science, technology, management, banking, production, etc.

Figure 1.1 Summary Classification of Computer Uses

Other uses of information processing. A number of other potentially interesting categories are listed in Figure 1.1 but without elaboration since they are not central to this discussion. Nevertheless, users should consider educational implications of computers in administration (accounting, scheduling, planning, etc.), research (institutional, sociological, psychological, instructional, etc.), and the relation of instruction to various applied uses. The last area is especially important because of increasing needs for training in computer use for jobs in science, technology, management, banking, production and retailing.

B. Intended Audience

The documents of Project CLUE are arranged in several sections to meet the different needs of three audiences: 1) students of educational technology and interested laymen; 2) educational administrators, teachers and instructional system managers; 3) educational psychologists and computer scientists.

To the student and layman, the report offers an introduction to the present performance, problems, and potential of computer uses in education. Samples of instructional programs and their uses have been annotated. Technical terminology has been minimized in the summary and interpretive sections. Much of the specialized vocabulary for the field is clarified by common language definitions and examples in a glossary (Appendix E of Volume 1).

The administrator or teacher who is already familiar with the debate about computers in educational technology will find the guidelines for using computers in education most valuable. He may also acquire background information to support planning of project proposals and new programs.

For the specialist in the research and development of instructional uses of computers, materials from which the guidelines were derived provide detail on differing opinions regarding computer instruction, dimensions underlying computer use in education, and comments on system design. The index should assist in locating material on specific subjects or learning the opinions of certain writers.

The first volume offers a perspective on the purposes and goals of the study, provides an interpretive overview, and presents guidelines for computer use. Five appendices include annotated examples of instructional programs, abstracts of representative educational projects using computers, a listing of the domain for instructional uses, a glossary, and a guide to other sources of interpretation, reports, and recommendations. Students, laymen, administrators, and teachers should find parts of Volume I useful.

The second volume of the report includes six position statements: operations and costs, development of computer-based learning materials, programming languages, evaluation of materials and strategy, research on instruction and learning, and documentation and distribution of information and learning materials. Each position statement incorporates interpretation and reaction from persons knowledgeable in that area. Bibliographies placed at the end of each statement include references to all persons and papers from which the statements were derived as well as a few suggested readings.

The four appendices document the method of the study and dissemination, list projects contacted,suggest activities for professional societies and other organizations, and offer notes on computer system design for instructional uses. Educational researchers and computer scientists should find some parts of Volume II of interest.

C. Chronology of Project Activities

A framework for discussion and review activity was derived from published reports on computer use during the early months of Project CLUE (January through March 1969). Staff members searched for current and relevant materials in order to interpret what was being done, what had been planned, and what was judged to be most needed and important. Project directors and other persons active in research and development programs throughout North America responded to requests for materials describing their current work. Staff members visited many sites of interest and attended meetings and conferences at which computer uses in instruction were discussed. Details are given in Appendix A of Volume II.

Drafts of five statements of points of view were assembled during the summer and mailed to all persons quoted directly and to other interested and knowledgeable individuals in the field. Revisions were made by Project CLUE staff during the fall and winter, and a preliminary draft of the statements was distributed for review and comment in February 1970.

The appendices were assembled during the spring of 1970 and distributed to obtain confirmation and correction of information given about persons and institutions mentioned. Most of the documents were revised during the summer and were distributed for comment by participants at three major conferences in August and September: the IFIP World Conference on Computer Education, the Education Sector of the ACM 70 Convention, and the Conference on Computers in Undergraduate Science Teaching. Discussion at these meetings shaped yet one more revision before publication for wider distribution.

Throughout the project, CLUE staff members coordinated their efforts with those of other projects reviewing the use of computers in education, including: a study of the computer in higher education, RAND Corporation; a survey of computer uses in college teaching, MIT; program planning by the National Council for Educational Technology, London; and numerous single conferences and symposia.

2. SUMMARY OF GUIDELINES

The state of computer technology for instructional uses is well established; applications and further development should proceed. Computer systems and programming languages are available which are adequate to the tasks involved in development and presentation of learning materials. Applications have been demonstrated for various kinds of computer use and in a wide variety of subjects; many of these are available through telephone connections with regional computing services, and availability for some is extended nationally by networks of computers. Perhaps the biggest problem facing the potential user concerns the identification of the resources available to him and then selection of the most appropriate among them. Matching the right kind of computing system, programming language and automated learning resources to the requirements, needs and objectives of the learners can make the difference between success and failure for an applied project.

In order to take advantage of the developing computing technology in learning and teaching, it is important to begin more work now. Institutions, sponsoring organizations, and professional societies should provide greater incentives for the development and effective use of quality materials in instruction.

The intended audience for the guidelines presented in Chapter 4 of this volume includes the potential author, user and manager of computer applications in the instructional process, and secondarily, the possible sponsor, whether it may be a government agency, state office of education or the administration of an individual school or college. A summary of the guidelines in Chapter 4 follows here.

A. Management, operations and costs of computer uses in instruction.

The most effective uses of computer-related innovations will depend in the long run on significant reorganization of institutions. Many forces, social, political and economic, are pressing for greater responsiveness of educational systems to individual needs and a changing society. Certain of the computer-oriented techniques will help institutions meet the needs of individuals and society.

Computing resources are now available at a modest cost, and the expense of computing aids will continue to decrease. It is important to select carefully among the options available, and to plan for effective use of future capabilities. People are the most important resource, and incentives should be established to encourage the participation of the best available authors, teachers, technicians and other contributors to innovative activities.

The funding of innovation should cover the time necessary to confirm the effectiveness of new resources and techniques, and to bring the best ones to fully operational status within educational systems. Cost effectiveness in the short run should not be the major consideration in a decision to introduce computers into instruction and course development programs; the benefits in the long run, which follow from introducing computing and information processing now, are worth some additional investment at this time.

B. Development and evaluation of computer-based learning materials.

A broad context should be established for review and planning of the appropriate place for computing activities within curriculum and learning activities. Determination of goals should precede selection of methods and media. Both analytic and heuristic approaches to materials development will contribute to the growing library of computer-related curriculum resources.

The management of a computing facility for development and instruction should be oriented to its users: authors, teachers, administrators, and especially, students. Effective support for users, in the form of reference materials, demonstrations, training materials, and consultation as well as programming assistance, is a major consideration in furthering efficient and effective development activity. The same requirements for user support apply to the assistance the author should provide the teacher and student using computer-related materials. The automation of some special assistance to the user is quite promising.

Better incentive systems must be established to encourage curriculum development, distribution and maintenance. Both professional and economic rewards should be provided by various institutions and organizations in the educational system.

C. Programming languages and implications for instructional strategy.

No one language can be right for all users; each mode of computer use has special requirements, and different styles of program preparation benefit from different language features. Although no languages will be widely adopted as standards, translation among languages of similar purpose will be quite practical. Exchange of materials will be facilitated by improved documentation. (Section E, below, considers transfer from one project to another.)

The needs of the learning environment should determine the procedures or information processing used; language should be shaped by the instructional uses for it. To remain flexible, a project should work within a general-purpose system, providing more than one suitable programming language, or use a preliminary translation stage, probably automatic, to go from notations convenient for the authors into the programming language of the particular instructional computing system. The key to serving a variety of user needs is adaptability to individual requirements of authors and topics of instruction; probably this will be achieved through automatic means for extension of languages.

Programming languages and learning activities using computing should be selected and shaped to take advantage of opportunities for interaction between the learner and the collection of relevant information and procedures stored in the computer. Responsive computing resources supporting an environment for problem solving can be arranged in convenient, task-oriented packages for use in the solution of problems and exploration of data bases.

A curriculum development group should ultimately remain free of the constraints of specific languages even to the extent of avoiding use of the computer when the available software and programmers cannot implement the important features of an instructional strategy. On the other hand, persons or projects committed to exploiting the computer in education should select carefully among possible applications for those which best match computer contributions to the needs of learners. Furthermore, the development of information processing tools for learning should be pursued with a subject or discipline orientation rather than exclusively within the special area of instructional technology.

D. Introduction of computers into instruction.

Determination of needs and goals should be accomplished with full participation at the local level; concerned personnel at all levels in an educational institution should guide the development of new resources for instruction which will further the goals of the institution and those it serves.

An important multiplying effect on the return for resources invested should be obtained by applying appropriate effort through information centers and training programs. Exchange programs should help spread expertise among those who will become leaders in local projects.

A new project should avoid the use of the computer as a medium which may perpetuate inappropriate educational practices; imaginative uses of computing will emphasize general processes and problem solving more than specific facts and conventions. Training programs should help teachers and authors adopt a flexible and creative approach, attentive to the needs and reactions of individual students, and inform them about the implications of automatic information processing for society. Any program introducing computers into education, even if primarily for teaching other subjects, cannot ignore considerations of general computer knowledge and specific skills of computer use.

Computer-based systems should be introduced into curriculum and instruction only to the extent that they make a better contribution for meeting educational needs than alternative systems and procedures. The use of the computer by students as a tool under their control, for learning and problem solving can be recommended strongly. Management of records and materials students directly as well as through teachers and administrators, is a promising application. The presentation of instruction (exposition or remediation) via the computer may contribute significantly to learning and the development of a favorable attitude by some students having special needs resulting from learning disabilities, cultural differences or gaps in educational background.

One practical approach to computer use in the instructional process is to make the information processing tools and data bases directly available to the learner and let complex human skills and judgment of children and young adults be applied where scientific knowledge of the learning process is inadequate to make specific prescriptions. In general, the scholar-teacher should remain in charge of the introduction of computer technology into the teaching and learning activities, attending to the uses of the computer in his area of study, and to the advice of experts on technical matters, and most of all, to the reactions and performance of individual learners.

E. Transfer of findings and materials from one project to another.

Each project should produce documentation which warns others about the shortcomings of an approach as well as provides encouragement to follow successful lines of development. Although the equipment used at one site may not be generally available, the successful applications can be described in procedural terms from which adaptations can be prepared for other equipment.

Authors should be provided greater incentives to document, distribute and revise computer-based exercises; economic and professional rewards should derive from a distribution system involving institutions, professional organizations, publishers, computing software organizations, and computer manufacturers. A first step is the early development of reviewing activities and other programs in professional societies which will increase the amount and quality of materials developed.

National and international programs should help distribute knowledge and expertise as well as computer-based materials. Prospective personnel for a project planned at one site should work for a time at another site which is already operational. A mobile team of experts might move from place to place contributing to the effective and economical establishment of new projects at schools and colleges. A few sample programs, demonstration systems and portable terminals should be available for trial use by any institution considering the establishment of a new project.

Sources of information and consultation should be maintained by national and regional centers, which are coordinated with similar centers in other countries. Conferences on computers in education should be held regularly, some of them quite broad in scope and others specific to areas of teaching and to components of the technology. Participants should include students as well as teachers in the relevant disciplines, and also potential employers and others who may be served by education and training involving computers.

3. INTERPRETIVE OVERVIEW

Instructional uses of computers have been under investigation for more than 10 years, and the field continues to change rapidly from year to year. The purpose of this overview is to provide a framework for discussion and recommendations, a few specific examples of current and promising uses, and references to more detailed information about research and development in this field.

A BRIEF HISTORY

Plans were begun on at least three projects in 1958. A demonstration of computer teaching of binary arithmetic was made at IBM's Thomas J. Watson Research Center, Yorktown Heights, N.Y., and was reported by Gustave Rath and others in the book Automated Teaching edited by Eugene Galanter (Wiley, 1959). Another research effort started at System Development Corporation, Santa Monica, California, about the same time; the computer was used to control a random-access projection device for presenting pages of material in research on branching modes of programmed instruction. J.C.R. Licklider and John Swets, both of Bolt Beranek and Newman, Cambridge, Massachusetts, were looking at a variety of computer uses in 1958 and 1959; one instructional application was the construction of graphs in response to requests made by students in analytic geometry.

A second project at the IBM Watson Research Center grew out of William Uttal's work on teaching machines; he required more logical capability than was conveniently achieved with special purpose circuits in non-computer devices. A project initiated by Donald Bitzer and Daniel Alpert at the University of Illinois at about the same time gave particular attention to the design of convenient learning stations for the student and simplified program entry procedures for the curriculum author. A conference sponsored by System Development Corporation and the Office of Naval Research in October of 1961 included a good sampling of work on computer-aided instruction and related fields. The proceedings of that conference (Coulson, 1962) still constitute a standard reference on instructional applications of computers. Five major projects (and perhaps 11 different curriculum packages) were reported at that time, although more than half of the packages were short demonstration units.

The number of distinguishable projects and samples of instructional materials probably doubled by 1963, two years after the first conference. Curriculum packages designed at System Development Corporation and Watson Research Center had been used successfully with over a hundred students. A survey conducted in 1965 showed that the number of projects and materials had doubled again in two more years. Many of the curriculum programs were quite substantial and one of them at the University of Illinois was in use for regular credit instruction.

The problems and potentials of this young technology were discussed at three significant conferences in the fall of 1965: The Computer in Physics Instruction (Commission on College Physics, 1965), Computers in Higher Education (Gerard, 1967) and The Computer in American Education (Bushnell and Allen, 1967). The proceedings of those sessions are readily obtainable and together make up a useful collection of examples, opinion and projections. To obtain references to the most current information and opinion in this field, the reader should use Appendix A, a guide to information sources in the area of instructional uses of computers; this document is also distributed by the ERIC Clearinghouse on Educational Media and Technology, Cypress Hall, Stanford, California 94305.

Special sessions on computers in education began to occur regularly at meetings of American Educational Research Association (AERA), Association for Educational Data Systems (AEDS), National Society for Programmed Instruction (NSPI), Association for Computing Machinery (ACM), and the Fall and Spring

Joint Computer Conferences of the American Federation of Information Processing Societies (AFIPS). Conference members expressed continuing enthusiasm about limited successes with existing applications, but they were becoming sceptical of initial claims for extensive instructional possibilities with computer technology.

Manufacturers and publishers were quite active in the area about 1965, making increasingly large capital investments. IBM, RCA, Philco-Ford, Technomics and Computer Systems for Education officially announced the preparation of special-purpose computer-aided instruction systems. Activities were also taking place within Westinghouse, Honeywell, GE, CDC and Burroughs. Sizeable field studies were conducted in several public school systems, particularly Philadelphia, New York City, McComb County, Mississippi, and Waterford, Michigan, as well as in several schools working directly with Stanford University. Use of interactive computing systems to teach computer programming and mathematics was spreading rapidly; two of the first projects involved public schools in the vicinity of Boston (Project LOCAL) and both public and private schools near Dartmouth College, Hanover, New Hampshire.

Another set of conferences and review studies define the state of the new technology for instruction in 1968. The College Entrance Examination Board and the Social Science Research Council sponsored an invitational conference at the University of Texas in October of that year; the papers and critiques prepared especially for that meeting were published by Harper and Row in 1970. The Interuniversity Communications Council (EDUCOM) had a working group look at programming languages, documentation, and validation problems in instructional applications of computers. The final report of Phase I, supported by the Office of Naval Research, is available from EDUCOM in Boston (100 Charles River Plaza, 02114). The Office of Education established a pilot project (called CUES) to explore the full range of practical computer applications in secondary schools; the plan was developed from feasibility studies conducted by IBM and General Learning Corporation and a review and extension by Computation Planning, Inc. The ERIC Clearinghouse on Educational Media and Technology at Stanford University distributed a pair of position statements on current practice and future trends by John Feldhusen and Robert Morgan.

A study of computers and instruction is being conducted by the RAND Corporation, Santa Monica, California, for the Kerr Commission on Higher Educaton, and another by staff at the MIT Sloan School of Management. This overview is taken from the final report of a study just completed at the University of Michigan using the code name Project CLUE. All three efforts were coordinated by their directors, and arrangements made for contributions to related conferences such as the Symposium on Computer-based Learning Systems organized by the National Council for Educational Technology in the United Kingdom.

Another round of conference activity in 1970 almost duplicated the set of meetings held in the fall of 1965. The University of Iowa and the National Science Foundation organized a Conference on Computers in Undergraduate Curricula, and it was well attended by authors and potential users of computer-based learning materials. The Commission on College Physics organized another look at computers in science teaching, reviewing progress since a 1965 meeting. Following the leadership of the International Federation for Information Processing, several groups cooperated in the first World Conference on Computer Education; it successfully brought together persons working on educational training programs for effective use of computers (e.g., training computer programmers) with persons working on the effective use of computers in education (e.g., supporting instruction in biology or classics). The ACM annual conference included a major section on education with particular attention to computers in the instructional process. The Center for Education Research and Innovation (CERI) of the Organization for Economic Cooperation and Development (OECD) held two meetings (March and October 1970) to examine computers in higher education and to explore prospects for increased cooperation among projects in different countries. Another pair of OECD meetings in March and December of the same year looked at computer studies in secondary schools, giving special attention to curriculum and to the training of teachers.

The field has grown to such a size that it is difficult to cite all of the work in research and development. Over 200 distinguishable projects of some magnitude are in operation and more than 1000 samples of curriculum materials using computer presentations have been noted, although perhaps only 40 of them are full courses. Abstracts and interpretation of projects and instructional strategies can be found in periodic literature such as the Review of Educational Research, and in information files such as those of Entelek Incorporated, Newburyport, Massachusetts, and the Instructional Media Laboratory of the University of Wisconsin at Milwaukee. (See Appendix A.)

The field continues to grow in 1971 in spite of cutbacks in federal spending. The technology continues to change rapidly and considerable variety is apparent in systems, programming languages, and instructional strategies. Although it is difficult to characterize this diversity in a few pages, the following sections include a variety of specific examples.

CURRENT FACILITIES AND USES

Many different kinds of computer and software systems are being used by research and development projects today. Some small machines have been programmed for use by one student at a time executing stored programs, simulations, or designing his own computation routines or computer-based games and test exercises for other students. One of the first was a Digital Equipment Corporation (DEC) PDP-7 used by Harlan Lane and others at the University of Michigan for training and research on language skills. Systems that are somewhat larger but in a similar way dedicated to interactive instruction have been programmed for simultaneous use by anywhere from 4 to 40 students. Larger systems are in operation which can handle up to 200 students using the same or similar application programs; systems for up to 4000 simultaneous users have been planned. At present it is difficult to find 4000 or even 200 students who want to use similar programs at the same time and place, and an institution whose administrators wish to pay the price.

Other research and development projects have used general-purpose conversational systems, imbedding the instructional applications among other software packages available to users. Under these conditions, the student may use the same computer for controlled instruction sequences, self-testing, simulation, gaming, and problem-solving. Time-sharing computer systems at System Development Corporation, MIT and Dartmouth were early examples of this general-purpose approach, although the designers of these systems probably did not consider their work to be related to computer-assisted instruction.

Programming languages and systems ("software") exhibit even more diversity than the computing equipment ("hardware"). More than 40 languages and dialects have been developed specifically for programming conversational instruction, but many of their differences are superficial and some obvious needs of users still have not been satisfied. There is good reason for different languages; at least five different kinds of users have distinguishable requirements: instructors, authors, instructional researchers, administrators, and computer programmers working with any of the first four types. The characteristics of different subject areas also necessitate different language features. Although the existing languages cannot be arranged neatly by user or application, one attempt is shown below, organized by the way the instructional programming looks to the lesson designer. Only a few examples are given for each kind of programming. The report (Zinn, 1969) from which this was taken provides a preliminary assessment of how well user needs are being met and considers common practices.

in languages and documentation. A later report (Zinn, 1971) offers additional interpretation and recommendation.

Languages for description of successive frames or items:

COURSEWRITER I for the IBM 1400, COURSEWRITER II for the IBM 1500, and COURSEWRITER III for the IBM 360, all products of International Business Machines (IBM).

COMPUTEST, COMPUTEST-II, prepared for various machines by staff at the Computation Center of the University of California, and PILOT, San Francisco.

COPI I and II for the UNIVAC 1108, developed by UNIVAC in Minneapolis.

TUTOR for the PLATO III and PLATO IV Systems at the Computer-based Education Research Laboratory, University of Illinois, Urbana.

PLANIT, developed and distributed by System Development Corporation, Santa Monica, California.

Languages for description of procedures by which material (in curriculum files) is presented:

TSA, prepared for a PDP-I at the CAI Laboratory, Institute for Mathematical Studies in the Behavioral Sciences, Stanford University, Stanford, California.

ISL-1 and ISL-2 for the RCA, Instructional Systems (70 and 71), Palo Alto, California.

XXXX (University of Minnesota, Minneapolis)

FORTRAN, ALGOL, MAD, SNOBOL, TRAC, and other languages in general use for scientific programming applications may also be used.

Languages for specification of an environment for programming and problem solving:

APL was based on specifications for "A Programming Language" by Iverson in 1962 and is now a popular language for time sharing systems.

BASIC, developed at Dartmouth College in New Hampshire, is now the most widely available of the convenient (student-oriented) programming languages.

JOSS was the first of the on-line, interactive programming languages, and the designer Jules W. Schwartz at Rand Corporation set a model for many others which followed (TELCOMP, PIL, CAL, BRUIN, ISIS, LCC, and others).

POP-2 was developed by researchers at the University of Edinburgh and is now available commercially.

RUSH is an on-line version of PL/1 prepared by the Allan-Babcock Company for its time sharing service.

TELCOMP, ISRCOMP AND STRGCOMP were developed at Bolt Beranek and Newman, Cambridge, Massachusetts, and TELCOMP is available commercially.

Instructional materials have been written in almost all subject areas and for many age levels: preschool reading, elementary school science laboratory, intermediate school social studies games, high school biology laboratory, college mathematics, introductory German, chemistry laboratory, and professional school exercises in business management, medical diagnosis, architectural planning, etc. Some of the samples probably make little use of the computer as an information processing device and would be as effective and less expensive in another mode, e.g., a book or film cartridge.

The costs of using these various operational or experimental systems and languages vary considerably. Figures reported by manufacturers or research projects range from $0.25 to $15.00 per hour. Some of the differences can be attributed to variations in assumptions about how many effective student hours can be scheduled in a month or a year, whether the equipment is rented, leased or purchased, and how much time will be spent in utility jobs, preventive maintenance or repair. The Computer-Based Education Research Laboratory (CERL) at the University of Illinois (Urbana), plans to achieve a figure of 30¢ per student hour at consoles including heyboard, graphic display and image projector, with all curriculum development costs included. The project plans to be operating a few hundred such user stations over telephone lines by the end of 1972, and is discussed by its originators, Bitzer and Alpert (1969).

Whatever the hardware and communication costs may be, the initial financial hurdle is the high cost of investment in curriculum design and validation. Estimates range from $20,000 to $2,000,000 to produce 100 hours of adjunct material for a one-year course. A complete cost analysis must also consider the space, proctors on duty, reorganization of other curriculum or school functions, and other factors of operations and institutional change. Detailed discussions of economics have been published by Kopstein and Seidel (1968), Randall and Blaschke (1968), and Sharpe (1970).

Factors Affecting the Value of CAI

The value of computer assistance for self-instruction depends on many factors: the organization of the subject matter, the purposes of the author, the natural mode for presentation of the subject, and the personality of the student. Before self-study material in text format is adapted for computer presentation, the potential contributions of an automated instruction system should be considered. First, the machine evaluates a response constructed by the student, using the author's key as a standard; an automated procedure prints out discrepancies, tallies scores and selects remedial or enrichment material. Second, the machine can conceal and to some extent control the teaching material so that the author can specify greater complexity and assume more accuracy than is possible when the student is expected to find his place in the pages of a large booklet. Third, the computer can carry out operations specified by the student in simple programming languages or design systems. Fourth, the author or researcher obtains detailed data on student performance and perhaps attitude, and convenient summarization of student accomplishment ready for interpretation. Fifth, the author is able to modify his text and prepare alternative versions with relative ease.

Perhaps an adjustment of goals and an application of new techniques will achieve more dramatic results in individualized learning activities than simple computerization of text. For example, developers might give greater attention to effective interaction between man and machine during the learning process: what should be done by each person involved, and what should be done by the machine? A dynamic information system might serve as a common working ground for a scholar and learner; could they share a computer-based, primary-source "textbook" that is being updated continually by the scholar and annotated occasionally by each student who uses it?

Serious students and conscientious university professors sometimes work together in an effective way to prepare a book; this opportunity could be extended to any student and instructor willing to invest some mininal effort in an innovative system. The institution of the college lecture has been described as "the least efficient means for getting partial information from the notes of the professor to the notes of the student without its passing through the heads of either." More flexible scheduling in educational institutions and freer student-professor exchanges suggest that a common working environment including the notes of the professor in addition to various primary sources of information would be quite welcome. In a similar way, an automated information system could help a learner and teacher share a common working environment for hypothesis testing, sometimes artificial as in computer simulation of physical and social processes (e.g., a model of evolution), and sometimes real in the sense of actual data from experiments (e.g., election returns or radiation measures).

Some computer users suggest that the most important contribution of computers to instruction and learning is the increase in accessibility of information processing tools for learners and other users. A large number of projects, most of them not considered to be computer-assisted instruction in a narrow sense, have shown viable alternatives to strictly specified instructional strategies for computer use in the schools today.

Whatever the technique or philosophy of computer use, the extent of use will ultimately be determined by judgments of appropriateness by subject experts, effectiveness observed from records of student performance, and costs which must be met by administrators of schools or training programs. Favorable economics for regular use of automated self-instruction may depend on computer aids for preparation and revision of material, self-modifying strategies of instruction, and automatic assembly of additional teaching samples or testing situations. Some of the limitations imposed by present computer technology involve the cost and unreliability of processing lengthy verbal constructions, the difficulty of sensing complex physical constructions, and inability to interpret bodily gestures or vocal intonation. One of the most difficult problems to overcome, however, is lack of organization of the subject matter. Somehow human teachers manage to be reasonably successful in spite of undefined objectives and unorganized material; computers (and educational technology in general) require much greater specificity in directions for instruction prepared by curriculum experts.

Machines and automated self-instruction are part of a larger system which includes human teachers; interactive instruction systems will become increasingly important because of the teacher's inability to provide adequate supervision during learning exercises. Teaching machines can encourage students to practice independent searching and self-teaching, as well as monitor and assist the students when they are given difficult or ill-defined tasks. Computer assistance will be used as a tool by curriculum planners, lesson designers, and teachers as well as students to achieve common educational objectives. The next section describes typical uses in several major areas.

Examples of Current Uses

Several modes or uses of computers in instruction are listed in Appendix D and samples are given in Appendix C. The material in these pages exemplify just three major kinds of uses for students. They are followed by a description of computer aids for an instructor, curriculum author, or researcher.

One of the underlying dimensions of applications for students is that of author or program control. At one extreme, the student can do only what the program allows; typically he finds himself more restricted than he is with a textbook or set of dittoed exercises. At the other extreme, the computer is programmed to serve the student as a tool in the management of information necessary for solving problems, and the student is given almost complete control. It is also possible for the lesson designer to program the computer to respond in set ways but leave the initiative to the student; the learner is encouraged to explore the materials or model by whatever means he finds most efficient or interesting.

Drill, Tutorial, and Dialogue.

Computer assistance with drills and presentation of text is most often given the label "computer-assisted instruction" (CAI). Many student hours at a terminal have been logged with drill exercises because it is easy to assemble large amounts of material, assign it to large numbers of students, and service many simultaneous users on a relatively small machine. However, if economic criteria are important, the users must consider alternate ways of achieving the objectives which can be met by computer-delivered drill exercises. The best known examples of drill in regular instruction is the elementary school curriculum for mathematics and language skills developed by Patrick Suppes and Richard Atkinson and tested initially in the schools of Palo Alto, California, McComb, Mississippi, Waterford, Michigan, and New York City.

Other applications have been used for language instruction at the college level. One project which has accumulated many hours of student experience is the language laboratory at the State University of New York at Stony Brook. A course in Russian was developed at Stanford which combines computer-delivered practice with other language laboratory exercises and individual meetings with the instructor.

At the University of Michigan a student console was especially designed for use with a small computer for training prosodic characteristics of speech. The aural response from the student is compared with the recorded model just played for the student; the extent and direction of discrepancy in pitch, loudness, or tempo immediately register on a zero-center meter. Progress with the exercises is determined by the individual performance of each student. The computer is used to average the signals in order to cancel out the differences in base pitch or loudness (e.g., a female student responding to a male, native-language speaker), to adjust the tolerance for error in response to student performance, and to convert the audio parameters from physical units to the logarithmic, psychological units more meaningful to the learner.

Many hours of instruction have been prepared in the tutorial mode probably because this manner of computer use is familiar and comfortable for a college professor interested in educational technology. Much of the work done at Penn State, Florida State, and other university-based projects can be characterized as individualized, tutorial adaptations of lecture or textbook material. Many dollars have been invested in the development of a few computerized, programmed-instruction courses; a significant part must be spent for implementation of a particular computer system.

Some instructional programs of the tutorial variety are designed to encourage additional initiative on the part of the student, and to provide a relevant reply to whatever questions, comments or conclusions he may type in. Typically, the author of such an exercise has provided in the computer program a set of conditional statements which, for any stage of discussion, make the computer reply dependent not only on the student's current inquiry or assertion, but also on the history of the conversation. The classic example of this type of use is a medical diagnosis exercise developed by Feurzeig and others at Bolt Beranek and Newman. The learning situation is characterized by stages of examination and laboratory tests alternated with "discussion" of a tentative diagnosis with an automated mentor. The computer program keeps the student on the right track, and responds to his diagnostic attempts in light of information he has already acquired. An example of a notation suited for describing such learning exercises is given in Figure 3.1. Annotations on the program appear in brackets.

Problem solving exercises in physics have been programmed by Edwin Taylor and others at MIT to provide information at the request of the student and

```
GENERAL "Proceed with investigation."       [messages within quotation
                                             marks are typed for the student,
                                             annotations are in brackets]

  ACCEPT                                    [accept directive from student]

    IF /suspects/                           [did the student mention
                                             "suspects"]

      1) "Wife, brother and partner."       [first time, tell him this]
      2) "No new suspects."                 [second time, type this]

    IF /lab, rifle, glass, pipe/            [did he ask about any of these?]
      IF ALL REPORTS, GO TO LAB             [only after he has all reports
                                             permit him to request
                                             laboratory tests]

      "I advise you to check reports first."

    IF /interrogate/
      IF ALL LAB, GO TO INTERR
      "I advise you request lab tests first."
      "I don't understand."                 [if nothing is recognized in
                                             his directive]

  LAB "This is the lab."

    IF /glass/                              [if he mentions the "Glass"]

      IF WIFE                               [if he has already interrogated
                                             the wife]

           "Glass contained arsenic."

      1)   "Prints belong to the wife."     [otherwise these replies]

      2)   "Nothing new."

    "What is it you want?"                  [if no lab test request is
                                             recognized]

    ACCEPT

    TO LAB + 1                              [go back to process a new
                                             directive]
```

Figure 3.1: Sample of a notation suited for exercises in decision making

eventually to check his solution. The computer extracts key words and phrases from the student input for use in the reply assembled by the author's program, simulating a personal conversation. The programming language used by the author is an extension of one designed by Joseph Weizenbaum and called Eliza. A particular advantage of Weizenbaum's technique is that the program can be written to confirm each time what was "understood" by the collection of words recognized in the student's message.

The benefits unique to computer presentation and control have not yet been isolated. Some advantage is anticipated because the author is able to write instructions for processing constructed responses, branching according to complex strategies, and controlling and concealing material appropriately for each individual student. However, few lesson designers have made use of capabilities beyond those which can be accomplished with the printed format. Although the computer may have played a significant role in improvement of instruction by coercing the author into more careful organization, testing, and revision of material, in the end his self-instruction package may be presented to students almost as effectively (and requiring considerably less time and money) in booklets and audio-visual modules.

Simulation and Gaming

Applications in this category differ from the previous group in that the conversation between student and program, and the results the student obtains in playing the game or exploring the simulation, do not have to be programmed in detail by the designer of the learning exercise. In other words, the computer program underlying the game or simulation is a model designed to provide some appropriate reply to whatever the student may type as input for the model. Such programs can serve a variety of purposes: examination of the decision-making skills of a student during training, practice for a professional in problem situations which may not be encountered often enough to maintain essential skills, and theoretical tests of new hypotheses in abstract situations which, although artificial, may be easily manipulated.

Simulation for military and industrial training usually attempts to achieve maximum fidelity in order, as much as possible, to replace experience in a real airplane, space capsule, or business management situation. However, it is sometimes desirable to give students experience in abstract situations which emphasize first one concept or relationship and then another, with little concern for realism. Learning may be more efficient and effective where the content and complexity of a succession of exercises are carefully planned. Computer-based games may place the student in an even more abstract and less realistic situation. Typically, a game provides specific payoffs and introduces competition with other students. Applications of both gaming and simulation are found in elementary school social studies, high school career planning, college chemistry and graduate business training. A sample of a student exploring a simple concept in wildlife management follows:

A student is given practice in managing one aspect of a simulated salmon-fishing operation. The object of the game is to build up and maintain a population which will maximize the catch taken by the fishery. The size of the run for the coming year is determined by the computer in some way not known to the student, although he does know it depends on the previous year's escapement.

Conversation	Commentary
(Computer in capitals; player lower case and indented)	
WHICH MANAGEMENT STRATEGY DO YOU WANT TO ADOPT?	The player has the choice of setting either escapement or catch.
catch	
CATCH FOR 1969? 16,000	

```
ESCAPEMENT = 2,000
```

The computer supplies the size of the escapement, and asks about the next year.

```
CATCH FOR 1970?
  10,000

ESCAPEMENT = 1,000
```

The student notes that when 2,000 escape (1969, above) the next year's run is 11,000 (catch of 10,000 plus 1,000 escaping).

```
CATCH FOR 1971?
  5,000

ESCAPEMENT = 1,000
THE MEN AT THE FISHERY ARE
DISTURBED ABOUT THE LOW CATCH

CATCH for 1972
  10,000

NO FISH ESCAPED.  LET'S START
OVER AGAIN.
```

The student should have kept the catch down until the population had recovered.

```
WHICH MANAGEMENT STRATEGY
DO YOU WANT TO ADOPT?

  escapement

ESCAPEMENT FOR 1969?
  15,000

CATCH = 3,000
THE MEN AT THE FISHERY ARE
FURIOUS ABOUT THE LOW CATCH

ESCAPEMENT FOR 1970?
  15,000
```

The student holds firm because he expects a much bigger run the next year.

```
CATCH - 11,000

ESCAPEMENT FOR 1971?
  10,000

CATCH = 15,000

ESCAPEMENT FOR 1972?
  9,000

CATCH = 21,000
```

```
ESCAPEMENT FOR 1973?
  9,000

CATCH = 19,000

YOUR TOTAL CATCH FOR THE LAST
FIVE YEARS HAS BEEN 68,000
SALMON--13,600 PER YEAR.
DO YOU WISH TO DISCUSS THE
OPTIMUM STRATEGY NOW?
```

The student graphs the data so far, infers a relationship between escapement and the run the following year, and is ready to switch to a subprogram which will "discuss" with him the optimal strategy.

Aids for Information Handling

Convenient tools for automatic organization and retrieval of information should be useful to the student as they are to any scholar working with a broad base of information. A number of experimental systems show considerable promise but are still rather expensive. Procedures have been proposed, and some of them demonstrated, for student organization and use of large non-linear files of text which serve as individualized reference and instruction systems. The student can be given tools with which to reorganize and augment his personal copy of the basic file. In this mode students should be able to accomplish more scholarly work of greater quality during a given period of study, and to acquire more skill in searching for and organizing information, than is possible through discontinuous encounters with structured and strictly controlled tutorial instruction interspersed with periods of independent study. The development of curriculum files for this mode is significant because the role of the subject expert shifts from writer of a detailed, step-by-step introduction for a topic, to assembler of an appropriate data base for student exploration, and to consultant on the development of powerful aids for exploration and scholarly work within those files of information. One illustration is an experimental text-handling system developed by Douglas Engelbart and others at Stanford Research Institute. Although Engelbart's system has not been used specifically for instruction, exploratory projects are in progress elsewhere which may soon have interesting results to report concerning his techniques of "augmentation of human intellect applied in education."

Computation mode tends to be overlooked by the planner of the computer-based, instructional system, perhaps because it is such an obvious application, or because it does not look like tutorial instruction. A notable early experiment was conducted in the Massachusetts Public Schools (Project LOCAL) in association with Wallace Feurzeig at Bolt Beranek and Newman. Student programming and problem solving includes manipulation of symbols and words as well as numbers. Initially the students used remote computer services via teletype and phone lines; later, small computers were placed in five public schools for multiple use by students at four or five terminals.

College students and professional staff studying statistics on the System Development Corporation time-sharing system are able to evaluate one-line expressions, to write and execute simple computation routines, and to call on existing statistical packages. As the student moves from simple to complex problems, more powerful computational aids are placed at his disposal. A computation and graphic display system developed by Glenn Culler and B.E. Fried has been used by mathematics and science students at the University of California campuses at Santa Barbara and Los Angeles, and at Harvard University.

Computers are being used increasingly by artists and scholars to design or conduct research on musical compositions, creative writings, experimental films, and architectural designs. Students from these areas outside science and engineering can obtain convenient access to computing capability through well designed study carrels and readily comprehensible programming languages.

Aids for Instructional Management

It appears that public schools will be able to afford interactive computer assistance for a few instructors and administrators before they can reach each individual student directly. Aiding management of instruction is an appropriate beginning; knowledge gained through semi-automated handling of instructional materials and performance records will contribute to effective implementation of other interactive uses of computers by students directly.

The Oakleaf School project in Pittsburgh began with much dependence on teacher-student contact for diagnosis and interpretation and a large clerical staff for grading tests, checking resource tables and arranging lesson materials in support of individually prescribed instruction. Gradually the clerical burden has been taken over by automated procedures, and some of the more routine contact with students is being replaced by conversational interaction with computer programs.

Tools for Author and Researcher

Programming languages are needed which are convenient for specifying interactive instruction. An EDUCOM working group (mentioned earlier) has assembled a set of documents which describes various programming languages and identifies additional requirements of authors and researchers which are not presently satisfied. The report of Phase I of the EDUCOM study recommends increased facility for: expressing complex, conditional procedures; processing quantities of algebraic expressions typed by the student; assembling instructional material from elements of the subject matter and relationships among the elements defined by the subject expert; interactive editing and arranging of materials; automatic summarization and selection of performance data; and integration of automated instruction with computer tools for learning.

Some of the present experimental systems provide capability for interactive composition and revision of materials. Programs have been written by Leonard Uhr, Jonathan Wexler, Jaim Carbonell and others which generate the first draft of a computer-based learning exercise from a specially written text, a set of graded test papers, or a description of objectives for student performance at the end of the exercise. Existing examples may appear trivial; it is difficult to handle sophisticated learning situations now, but generation of materials is one of the trends discussed in the next section.

TRENDS AND NEW DIRECTIONS

A current trend in instructional use of computers appears to be away from the programming of sequences to be delivered by the computer under strict control of the author's sequencing rules. Putting a programmed booklet into a computer may be more a hindrance than a help to a motivated student who possesses reasonable study skills. More likely, managers of future systems will make the primary sources of knowledge directly available to students through organized files of information and procedures. For this mode of study students will be given the necessary learning tools for information management, computation, and composition. Computers and electronic technology will be used much more widely in the future world of today's students, and the responsibilities they will assume will require greater skill of information acquisition and decision making than is expected presently. This suggests that today students should learn to use information files and the associated tools for learning and productive work.

For selected students and certain instructional objectives the effectiveness of a computerized, author-controlled presentation will be sufficiently greater than experience with the same content in textbooks or audiovisual materials to justify the greater cost per unit of instruciton. For example, many children lack the verbal skills, discriminations, and attention span that may be needed for independent practice of some skills without the aid of a computer; students of any age dealing with written and spoken languages may for similar reasons need computer assistance for diagnostic self-testing of skills.

Expensive, on-line systems will continue to be used for research on learning and teaching and for development of self-instructional programs. Computers and communications are especially important because the training devices can be located in public school classrooms, business offices and engineering shops or laboratories, through which an information processing system can instruct, answer questions, deliver tests of understanding, record data, and test hypotheses regarding instruction and learning with great detail and over long periods of time. This capability to introduce experimental control into situations satisfying the real demands of education and training should help reduce the present discrepancies between contrived laboratory situations and actual applications of learning principles in training and education.

Research on natural language processing, information structures, and computer aids for human intellect, eventually will produce tools to augment considerably the resources available to authors of computer-based exercises. However it is very difficult to anticipate the details of such facilities for educational systems, and it is not clear how the instructional programmer would write directions for generalized language processing or definition of information structures if today's tools were put at his disposal.

Special-purpose computer programs can be written to assemble instruction materials from elements of a subject and relationships among these elements. A programmer can describe an entire class of problems with one set of computer statements (program) by which an indefinite number of test or instruction items are generated for presentation to each student as they are needed. For some learning exercises, writing a rule which generates sufficient variety will be rather difficult; if the number of examples needed is fairly small, the author will save time by writing out each variation he needs to have available. However, even when the technique does not save time in initial drafting, it will reduce the probability of oversight or error by the author composing the problem set. Furthermore, generative rules are likely to provide more possibilities for individual adaptation than a predetermined sequence of branches through a large pool of specific items.

Communication networks will play an important role in permitting the preparation and use of computer-based exercises within existing economic constraints. Expensive, instructional software on computers is not now used with large numbers of students. However, suitable networks will simulate and assist groups of subject experts who work together on computer-based materials for the same course at different schools. It may be argued that materials developed on a cooperative basis will be more usable at different institutions than if they were developed independently. Furthermore, guidelines for organization and documentation of computer-based exercises will make adaptation and use at another school easier, especially since the text can be searched and edited readily while producing new copy for local students.

Networks of regional computer services will distribute information-processing capability which individual institutions or community education programs could not afford independently. The National Science Foundation funded a number of experiments having central resources located at Dartmouth, Cornell, Oregon State, Triangle Universities Computation Center (North Carolina), Illinois Institute of Technology, and others, and one combining resources at three universities within the state of Michigan. The Educational Information Network project of EDUCOM has established a directory service and proposed common practices which should facilitate such regional exchange. A group of contractors of the Advanced Research Projects Agency (ARPA) has formed a network especially for experimentation in exchange of data, programs, and interactive use of computers. Ideally, the resources of entire regions will be made available to enrich and individualize the educational program of each student, no matter what his geographical location.

In general, the suggested directions of a review article three years ago (Zinn, 1967) have become established trends in 1970. However, Ted Nelson in an entertaining article in Computer Decisions, recently reminded his readers that developers may be underestimating the power of the computer for learning and the inclination of individual learners to explore. He included a picture of Mickey Mouse wearing the magical hat of the sorcerer (to whom he was an apprentice in the film) and playing with the stars. The caption reads: "If the computer is a universal control system, let's give kids universes to control."

In the Walt Disney film, Mickey played with the powers of the universe while his master was away, and spoiled it all by commanding the broom to bring water from the creek and pour it into a barrel in the cottage - a task Mickey didn't like at all. But he did not know how to stop the broom from carrying in the water, and the cottage was flooded.

Nelson seems concerned about a strong tendency to put in the computer those exercises which seem easy to implement and are uninteresting for humans to do. Lengthy courses of tutorial and drill are made operational without reviewing carefully whether the goals and practice exercises are worthwhile for the students at all.

Who is to control this new resource for self-education? Will the learner be in charge, and will he use the tools to his advantage, moving from apprentice status to full-fledged scholar and practitioner? Or will someone else play the apprentice role and risk inundating the learning environment with repetitious and irrelevant tasks? An electronic version of the sorcerer's broom might be directed to "bring knowledge," flooding a learning laboratory full of passive children with useless facts and non-adaptive skills, with the apprentice to this magical technology standing by unable to turn it off.

The opinions and preferences expressed by many of the contributors to Project CLUE indicate that the new resources for learning and extended intellectual performance will be used well in the future.

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4. GUIDELINES FOR CURRENT USES

On many occasions since the initiation of Project CLUE in 1969, the staff participated in discussions of guidelines and recommendations dealing with instructional use of computers. At each such opportunity the background materials and tentative findings of Project CLUE were introduced into the proceedings of the meeting through written statements prepared in advance and by participation in the drafting of recommendations on the spot. By this means of presentation, critical review and revision, the information and ideas were brought back to Project CLUE amplified and extended by the ideas of others not on the Project staff.

This section on guidelines includes many proposals which also appear in the various sets of guidelines and recommendations produced by conferences and symposia in which the Project staff participated during the last two years. Among the most significant ones for Project CLUE purposes are: a Unesco consultation on computer uses in instruction (March 1970), an NCET (UK) symposium on computer-based learning systems, two OECD symposia on computers in higher education (March and October 1970) and one on computers in secondary education (March 1970), a Rand Corporation meeting on computers in the instructional process (October 1970), the IFIP World Conference on Computer Education (August 1970), and three sessions of the ACM Special Interest Group on Computer Uses in Education (November 1969, May 1970, September 1970). A complete list of meetings and presentations is included in Appendix A of Volume II.

The intended audience for the guidelines assembled here includes the potential author, user and manager of computer applications in the instructional process, and, secondarily, the possible sponsor, whether a government agency, state office of education or the administration of an individual school or college.

A variety of positions are represented in the guidelines selected from the position statements of Volume II and other sources. Some apparent discrepancies among viewpoints can be accounted for by a difference in the time perspective, e.g., how soon changes in institutions can be expected to occur. Other possible conflicts in priorities are attributable to the difference in the perspectives of research and development as contrasted with teaching and administration.

The guidelines propose action by a number of different individuals and institutions. Although the agent of action should be clear from the context, a listing may be helpful here to indicate the scope:

International organizations such as OECD, Unesco and IFIP.

Government agencies including education authorities, research funding agencies, and special commissions.

Professional associations concerned with computer uses in education and training.

Consortiums of institutions or individual projects.

Educational institutions, considering administrators, teachers, and students.

Individuals working on development of computer uses and related materials.

The guidelines have been arranged in a listing of short statements grouped in five major categories:

A. Management, operations and costs of computer uses in instruction.

B. Development and evaluation of computer-based learning materials.

C. Programming languages and implications for instructional strategy.

D. Introduction of computer uses into instruction.

E. Transfer of findings and materials from one project to another.

References to the related sets of recommendations are included at the end. The glossary in Appendix E of this volume may be helpful to the reader unfamiliar with some of the technical terms used in the following guidelines.

A. MANAGEMENT, OPERATIONS AND COSTS OF COMPUTER USES IN INSTRUCTION

1. Requisite reorganization of institutions.

A tremendous discrepancy exists between ultimate promise and the immediate possibility of computer use. In the long range, success of computer-related innovations will depend on comprehensive reorganization of the educational system. The expected benefits of individualization and information processing usually are not compatible with the traditional structures and methods of operation of most educational systems today, although they are quite necessary for meeting the demands made by rapid expansion of knowledge and discoveries made in science and technology. However, introduction of computer-oriented techniques need not wait for reform; indeed, such changes might help bring about needed improvements. Optimizing apparent benefits in the short run can and should be balanced against systematizing the supportive processes in the long run.

2. Use of available, low-cost facilities.

Many of the existing computer installations could be used by schools lacking their own facilities. Most economical access is by a batch mode of operation, that is, by assembling a number of jobs to be done at the convenience of the computer operator. Batch mode and standard programming languages can be used to aid in the management of instructional resources or to execute programs which students have prepared as part of their course work. On-line, interactive use is sometimes only a little more expensive. In any case, use of spare time on a government, university, or commercial system should be contracted specifically to assure availability on an appropriate schedule for student use.

3. Priorities for educational computing systems.

In the management of computing systems which operate in a multiple-access or time-shared mode, instructional users should receive priority by some processing scheme which recognizes and services some users first, or a schedule that dedicates certain hours exclusively to student use. Other management considerations include:

small and perhaps mobile systems (minicomputers) which reduce or eliminate dependence on communication links;

effective, preventive maintenance and a supply of plug-in components, especially for equipment at remote sites; and

guidelines for common practices in programming and documentation to facilitate exchange of learning materials and procedures among different initiators and users.

4. Interpretation of cost estimates.

Costs reported for development of learning materials or for student use of system time cover a broad range; no one datum can be generalized since it depends on goals, manner of computer use, appropriateness of the computing system used, skills and preferences of the author, local personnel costs, outside consultation, learning materials already available for the topic, and the method of accounting for personnel, depreciation, software development, maintenance, and other costs which may not be explicit. The range of costs sometimes given (as in Volume II, Part 2) should not be used except as a very general framework for the immediate future.

5. Means of cost reduction.

Many means are available to reduce the cost of computer use

planned replacement of old with new hardware and software configurations;

use of special-purpose, low-cost terminals;

adoption of educational programming languages which provide greater economy in computer time.

coordinated work by two or more students at a terminal;

video projection or recording of the use of a computer by one student at a terminal for viewing by a group of students;

selection of computer contributions which can be accomplished in the batch mode of computer use at much less expense, for example, generation of materials for use off the computer, or computation in support of simulation games;

and text processing which helps identify weaknesses in writing and expression.

6. Planning for future capabilities.

In anticipation of future reduction in hardware costs, not only of terminals but also of communications and computer processing, most development of curriculum materials and the logic or strategy of instruction should be conducted in a modular and hardware-independent way so that component parts of instructional software can continue to be used alone or in various combinations as hardware configurations change. Decisions to initiate research and development projects should not be deferred because costs will be considerably less in a few years; the costs of delay could be considerable, for example, hurried training programs and errors in the engineering of systems. The development of instructional software and expertise must proceed if these essential tools are to be used effectively when the hardware and communications systems become economical.

7. Fund innovation and transition into regular operations.

Financing policies and plans should be developed and examined carefully since they have a very profound impact on the entire educational system. Financial commitment should be made for a sufficient length of time to assure an adequate test of an innovation. The sponsor should consider itself the major beneficiary of an educational project; the administrations and governing bodies of educational institutions should view new instructional programs as investments in the future, developing an important "natural resource."

8. Provide training and incentives for needed staff.

It is especially important to anticipate the implications of policies concerning the recruitment, selection, training, and payment of staff. The success of technological innovations requires a multidisciplinary staff which includes scientific and technical personnel expert in analyzing learning situations, assessing performance and training teachers as well as assembling computer hardware and software and managing applications. Existing educational institutions may not now provide candidates in the full range of skills and experience necessary for the variety of roles to be filled in a computer-related instructional system. Salaries and related incentives should be established to encourage the participation of the best available teachers, technicians, and other professional and para-professional contributors in innovative activities. Intelligence and creativity should be given greater consideration in selection of personnel than years of experience.

9. Assess value of change.

Cost, or cost effectiveness, in the short run is not the major consideration in a decision to introduce computers into the instruction and course development program of an educational system. The extent and scope of desirable changes brought about as a result of the introduction of computers and information processing certainly are worth some additional investment at this time in operations and in research and development. Development of new materials and techniques and the preparation of new teachers are particularly promising loci for efforts in educational reform.

B. DEVELOPMENT AND EVALUATION OF COMPUTER-BASED LEARNING MATERIALS

1. Establish a broad context for review.

Development of computer-related materials should be pursued in the context of the entire instructional system, and coordinated with materials developed and administered for other media and course components. A review and advisory board should monitor the entire development program on a periodic basis to insure the coherence of the total instructional program including the procedures and policies for evaluation of student performance and attitude.

2. Determine goals and methods first.

Analyses of objectives and instructional methods need to be made in relation to the characteristics of the students before the costs and benefits are considered. Alternative instructional configurations should be examined in the same frame of reference prior to a decision to use or extend a particular instructional innovation such as a computer-based interactive system (or any of the technical media) for large numbers of students.

3. Balance analytic and heuristic approaches.

The contribution of computer-mediated learning exercises to the quality of instruction will be known explicitly only if observable outcomes are specified, measured, and interpreted. The engineering of instructional materials to meet learner performance specifications requires the use of well-planned cycles of development, evaluation, and revision and is understandably expensive. Approaches which depend on heuristics (insights which may reduce the need for detailed analysis and trial use) usually are less expensive; they are directed at producing learning environments oriented to practice and production rather than "guaranteed-instruction" packages of the analytic approach. However, the development of a successful learning environment depends on the insight and dedication of its designers who must anticipate the motivation and skills of learners. Assessment of success depends on the judgments of experts in the discipline and in education, since the designers have not made an explicit statement of outcomes to be measured.

4. Select well-structured subjects for tutorial mode of computer use.

Authors of substantial amounts of computer-based learning material using the tutorial mode cannot afford the time to shape or tailor individually each line of text of each frame for each kind of student, but must devise stylized procedures and content descriptions from which many individual exercises can be derived automatically as needed for individual students. Therefore, initial applications of the tutorial mode of use of computers on a broad scale will be developed readily only for well-structured subjects such as language skills and mathematics.

5. User-oriented management.

Computer system managers should focus effort on developing, testing, and using instructional sequences and learning environments which promote desirable outcomes. Constructing, operating, and modifying the system of hardware and software should respond to the needs of users and not distort their objectives. Planning and costing curriculum components and arranging to amortize the cost over many students during a period of years are just as important as hardware planning.

6. Useful documentation.

Documentation is essential to economical maintenance and effective use of instructional programs. Guidelines for documentation, when widely adopted, should broaden the base of users of effective instructional programs. Documentation itself should be evaluated and revised on the basis of trial use by test readers typical of those for whom the documentation is intended.

7. Provide for expanded use of materials.

Extending the base of users beyond one subculture is a much more significant achievement than translation from one computer language and system to another. Important considerations include: language and idiom; cultural variables, in particular, attitudes toward teaching, achievement, inquiry and exploration;

and structures or procedures appropriate to knowledge and learning. Local trial of materials and programs is necessary and revision likely before computer-based learning materials can be used in another setting.

8. Favor qualitative improvements over cost reduction.

A development effort can and should demonstrate that successive iterations of materials produced are continually improving by relative measures of student benefits. To invest development resources in pseudo-scientific comparisons with some hypothetical "traditional" method is short sighted. The achievement of qualitatively different goals is more important at present than cost per hour of instruction time.

9. User support.

Distribution of non-computer supporting services is a difficult problem, not only in regional networks, but also in connection with local facilities which may require a user to go some distance to obtain documentation. Psychological distance of computing centers from users has been said to cause more problems than physical distance. Training and assistance for remote users of computing facilities should receive special attention now. Projects which put most of their resources into system development may find they have elegant software and communications which are unused.

10. Development teams and interaction among individual contributors.

Curriculum development should be considered in the context of the needs and contributions of different persons involved in the effective use of computers for instruction: students, teachers, scholars, and experts from areas of supporting technology such as computer and information sciences, psychology, engineering and instructional technology. These persons interrelate as they interact with a common base of knowledge and processes from which the student is to obtain some satisfactory representation or idea of the subject being studied.

11. Assistance for authors (including students).

Special assistance for curriculum preparation may be provided to an author of learning materials through automated indexing, retrieval and other information processing, and special requests may be made of him, for example, to document carefully his material and procedure which otherwise lie concealed within the computer memory. Similarly, assistance may be provided directly to learners who can usefully perform as "authors" reorganizing the information base, exploring new relations, and building up personalized files corresponding to individual representations of the knowledge.

12. Author incentives.

Incentive systems must be established to encourage curriculum development and maintenance. Professional and economic rewards should encourage potential authors, often working with others in an interdisciplinary group, to develop instructional systems. Recognition of quality work should be a factor in determination of promotion or other advantages. Economic incentives require establishing or improving copyright regulations for new media, including computer software.

C. PROGRAMMING LANGUAGES AND IMPLICATIONS FOR INSTRUCTIONAL STRATEGY

1. Universal language.

No one language can be right for all users. Each has a different background, goal and level of access to the system to be considered: student, instructor, lesson designer, researcher, etc. Each mode of computer use has special requirements, and different styles of program preparation benefit from different language features, from simple formats for describing curriculum material to be presented by stylized procedures, to system features with which to delimit a problem-solving environment.

2. Standards and translation.

Universality cannot be established by a group organized to set standards. Nor will any small number of languages (as justified by different requirements) be standardized effectively and widely adopted. Translation among languages of similar purpose is possible (and economic for some curriculum designs). Equipment differences, especially in the terminals (learner stations), cause most of the problems.

3. Computing system limitations.

System features impose definite limitations on language (and strategy). Hardware items, such as clocks, interrupt control, memory protection, and terminal controllers, limit what actions an author's procedure might take. Software for handling files, editing text, linking processors, and connecting simultaneous users of the system are important factors for some uses. Communications capacity, measured in bandwidth, elapsed time and charges, sets bounds on conversation rates, especially when diagrams and other graphic representations of knowledge are involved.

4. Shaping language in general-purpose facilities.

A language and its implementation shape the strategy of instructional uses to a great extent. It is better to have requirements of the learning environment determine the procedures or information processing used. A good way to remain flexible, especially for a research-oriented project, is to work within a general-purpose system providing more than one suitable programming language. At least one language or application program should provide a format for preparing computerized programmed instruction; others can be installed quite readily by compiling a specialized processor programmed in a common language such as FORTRAN. Others should provide for string processing, procedure writing, and interactive problem solving. Once a lesson designer determines what approach is likely to be successful with his students and teaching goals, that approach should be made more economical, and perhaps more convenient, through implementation of a specific language or notation.

5. Shaping language in special-purpose facilities.

For the project already committed to a restricted system, the best approach may be to prepare instructions using some more appropriate notation and to translate automatically, perhaps on another computer, into the code needed. Although use of a preprocessor should ease the task of the lesson designers and programmer-coders, the programs still will be no more economical in execution than allowed by the processor and system. The manager of facilities for a school or research project should have some options from which to select the best programming language for each purpose, and in some cases, the best machine.

6. System modularity.

Flexibility is important in a language design to allow adaptation to new ideas and opportunities. Economics is a primary consideration for a processor (or its compiled program) which will be used by many students. Modularity is an essential part of the design of systems (language processors) which are to be modified later or translated to another operating system. Documentation of any useable system (language) is essential for program maintenance as well as for user reference.

7. Language flexibility

The key to serving the variety of user needs may be adaptability, extensibility or flexibility, without trying to produce a general-purpose author language. Adaptations in any author's personal notation need to be made rapidly enough to keep him working effectively, and the eventual execution with many students needs to be economical. Translation may be through programmers rather than automatic processors, especially if the procedural programs are small. Procedures can then be applied to large files of curriculum data prepared in a format convenient for the subject expert.

8. Program descriptions.

Documentation (according to "publication" guidelines) facilitates preparation and revision of instructional programs, review by referees and potential users, and communication to programmers who are to implement instructional procedures and content in some other system and language. Natural language is not the ideal mode for describing learning exercises; some formalization of language appropriately requires the user to reflect on what he instructs the machine to do.

9. Exploit interactive mode of computer use.

On-line conversational use of computers is almost certain to be more costly than less glamorous means of access to information processing aids. However, the occasional user of computers is more likely to benefit from the interactive mode of operation than experienced or frequent users. Programming languages and learning exercises should be selected to take advantage of opportunities for the infrequent learner-user to carry on a dialogue with the system. For example, the learner should feel encouraged to test tentative ideas and try out possibilities, knowing the system not only will permit such explorations, but will help them to be successful. Suitable computer programs will keep track of loose ends while the user is sketching in ideas, accept details later, and provide an immediate and interpretable reply when the user's instructions are ambiguous or incomplete.

10. Develop problem-oriented software.

Creation of problem-solving environments, which should be distinguished from particular programming languages, is possible through the use of specially adapted command conventions and data structures. Computing resources can be arranged in convenient, task-oriented packages for use in solving problems and exploring data bases, as well as in non-specific, procedure-oriented languages. The artificial distinction between batch and interactive processing should be eliminated. Many systems already provide convenient means to move to the mode and terminal device most suitable, and programming languages will provide further support for optimum use of human time and computing resources.

11. Leave materials development open-ended.

A curriculum development group should remain free of the constraints of specific languages even to the extent of avoiding the computer when the available software and programmers cannot implement the important features of an instructional strategy. A software system should be adapted to specific uses and users; the managers should maintain clear subserviences of language maintenance and system operation to project goals.

12. Matching resources to needs and goals.

One general operating principle for persons planning projects in this area is to select carefully among possible applications of computers those which best exploit the computer role and to match computer contributions to the real *needs* of learners. At the same time, the development of information processing *tools* for learning can better be pursued with a subject or discipline orientation than within the special area of instructional technology. Information processing and computers will be used widely in all subject areas, and these new tools for learning and performance will interact in an exciting way with new goals and means for education.

D. INTRODUCTION OF COMPUTER USES INTO INSTRUCTION

1. Determination of local needs and goals.

It is difficult, if not impossible, for any group to design an instructional system without reference to the particular goals, needs, resources, and conditions of the specific community which will use the system. Indeed, the personnel who will be responsible for the technical implementation of the system should take a major role in planning sessions from the beginning. Concerned personnel at all levels in an educational institution should guide the development of new resources for instruction to support the goals of the institution and those it serves.

2. User-oriented manager.

The person responsible for the planning, development, and operation of an [illegible]uction-oriented computer system should understand students, the learning process, and the systems approach to instruction as well as technical matters. He should have available, on a continuing basis, the consultation of specialists in all relevant disciplines; but he should be given the freedom and responsibility to manage in a decisive way to serve instructional needs over all others. The convenience of student access to and use of technology should be placed above matters of system elegance and staff convenience. He should maintain a project staff which recognizes these priorities.

3. Multiplying effect through information centers and training programs.

Computers and information processing techniques should be introduced in a way which obtains a multiplying effect on the education system and on dissemination of knowledge. Crucial points for application of effort are information systems (such as libraries and vocational guidance services), teachers, and especially the trainers of teachers. The new technology must be supported by the development and distribution of new knowledge resources, including information about the technology and its implications for teaching methods, learning strategies, testing procedures and multi-factor evaluation. Fellowships and exchange programs should be used to develop expertise among those who may become leaders in local projects. Training programs at all levels of education should introduce new concepts of and approaches to education through technology and in particular through computers and information sciences.

4. Relevant dimensions of use.

In the selection of instructional uses for the educational program, planners must consider a number of salient dimensions as they interact with a particular situation: program or student control, extent of diagnosis and prescription, variety of information processing tools, amount of interaction, helping role of the computer, and the extent of restraints on expression and interaction. Selection must also be made among a variety of modes of access to computer systems (batch and on-line, alphanumeric and graphic, etc.).

5. An instrument of change.

A new project should avoid the use of the computer merely as a medium for delivery of a lecture or programmed text. This mode is quite prone to rigid application in an educational system and may preserve old practices (such as excessive emphasis on drill and recall of facts) rather than increase flexibility and student initiative. The introduction of automatic information processing, flexible information structures, and convenient communication links, on the other hand, is more likely than other technologies to facilitate innovation and change in education. Imaginative uses of computers will emphasize general processes and problem solving more than specific facts and conventions.

6. Favorable teacher experiences.

In order that new teachers will adopt a flexible and creative approach, breaking established patterns as a result of encountering computer use, they should: a) find computer-related materials useful and effective in their own training; b) test materials of their own construction in schools taking data from a number of interactions with individual students; and c) develop an improved perspective on information processing and its implications for learning and education by using the computer in their own work.

7. General computer education.

Vocational training in computers for some students and "computer literacy" for all students are desirable ends in themselves in view of the profound social and political implications of the widespread use of computers. Any program introducing computers into education, even if primarily for teaching other subjects, cannot ignore considerations of general computer knowledge and specific skills of computer use.

8. Immediate and visible benefits.

Some part of a national program to improve education should have an immediate and visible impact on social and economic conditions. For example, introduction of computers should include instructional aids for basic training in technical skills which will expand employment opportunities of trainees.

9. Comparison with non-computer alternatives.

Computer-based systems should be introduced into curriculum development and the instructional process only to the extent that they make a better contribution to solving the educational problems than alternative systems and procedures. For example, for the achievement of some objectives of teacher training and classroom reform, resources might be better spent directly on teachers and teacher aides, or on television, film, programmed texts, and other aids that are less expensive than computer systems and communications.

10. Community and continuing education programs.

The needs and interests of citizens cannot be put off until the next generation. Sound education about computing applications and the implications of information processing systems for the individual and society must be available to all ages, and the careful application of computing aids to learning and problem-solving activities should be extended to all learners without regard to age, institution or geographical location.

11. Tool for study and scholarly work.

The use of the computer by students as a tool for learning and problem solving can be strongly recommended. Certainly this kind of use accounts for a large proportion of current allocations of computer uses for instruction. This is not surprising; learning tools appear to obtain a great improvement in performance and a favorable change in attitude in return for the investment in time and computing resources. Activities recommended include simulation, gaming, modeling and design arranged to provide active learning situations for both student and teacher.

12. Assistance with records of individualized study.

Management of records and materials, preferably by students directly rather than through teachers and administrators, is a promising application. Any program of instruction which allows some flexibility in learning approach and rewards student initiative will require management of large files of records of student performance, and information about materials and learning exercises on an individual basis. Some projects have assembled files of such size and complexity that the computer is justified for reason of economy, reliability or accessibility of benefits to individual learners.

13. Meeting special needs of students.

Some students have special needs for whom the presentation of instruction (exposition or remediation) via the computer may contribute significantly to learning and favorable attitude. When a student lacks motivation or suitable orientation to the ordinary self-instruction resources, the machine provides a gentle pressure to proceed and to respond at each point of the essential sequence of instruction. (Nevertheless, one would wish to achieve for these students sufficient independence of thought and suitable motivation to proceed with self-learning experiences apart from computer tutorials.) For students lacking essential skills and opportunities for learning from present day language laboratories and group instruction, the careful sequencing and additional response processing done by computer systems appears to help.

14. Research on instruction and the development of instruction materials.

It is not necessary that the computer contribute to the learning of individual students; justification may be found in collection or analysis of data, opportunities for more complicated research designs, processing and summarization of data for the designers of learning exercises, etc. The presently critical attitude toward CAI of a tutorial nature for ordinary students in schools and colleges should, if anything, encourage increased investment in research on instruction and learning. When the process of learning is better understood and some models of instruction have been devised, tutorial use may become a significant tool in future computer-based educational systems.

15. New information processing techniques.

Diagnostic, tutorial, and other aids to be provided individual learners should be explored. The application of findings in the computer science areas of artificial intelligence, natural language processing, and question answering systems should be pursued vigorously for the benefit of educational uses.

16. Primacy of user needs and judgment of scholar-teachers

A practical approach to computer use in the instructional process is to make the information processing tools and data bases directly available to the learner and let complex human skills and judgment take over. A psychologist may prefer to engineer the stimulus-response chains and assess outcomes by objective measures. A research-oriented management might divert operating resources into educational and psychological studies of factors which have little effect compared with the advantages of time and structure obtained from reformulation of curriculum, and the amplification of performance based on powerful information processing tools oriented to the subject of study.

A computer scientist might divert attention from educational goals and instructional procedures to the attractions of a particular technology. The scholar-teacher should remain in charge of the introduction of computer technology into the teaching and learning activities, attending to uses of the computer in his area and study, and to the advice of experts on technical matters of system limitations, new information processing capability, parameters of man-machine interaction, reactions and performance of individual learners, etc.

E. TRANSFER OF FINDINGS AND MATERIALS FROM ONE PROJECT TO ANOTHER

1. Project documentation.

Each project should produce detailed documentation which exposes the weaknesses (as a warning to others) as well as reports the successes of the effort (as encouragement). Translation of the various reports for use in other situations should anticipate and try to reduce the confusion which often results from terms and examples specific to the local culture and conditions. When the equipment used is not generally available, the application can be described by procedures which might be adapted for use on other equipment.

2. Materials documentation.

One part of the documentation of a successful project should be a detailed and objective model for the process of innovation and change regarding computer contributions to teacher training, materials development, and direct instruction. This model should be sufficiently specific to provide the basis for various computer-based simulations of conditions and outcomes characteristic of many situations, and thereby contribute to the objective planning of other projects.

3. Distribution of new materials and research findings.

Authors should be provided greater incentive to document, distribute, and revise computer-based exercises. Potential users cannot choose wisely without more complete information, reviews, and evaluative studies. Curriculum development resources and training programs at regional centers would help to diffuse common practices and increase likelihood of exchange. Competing curriculum packages will be distributed through different time-sharing services, and decisions based on quality and economics will be made in the marketplace.

4. Guidelines for broadening the base of users.

Means to achieve wide use of effective learning exercises have been suggested: formalize and standardize procedures of journal review and dissemination; issue a periodic review of computers in education; provide better incentives to the author, e.g., academic credit, copyright protection, and reimbursement; improve documentation of learning exercises.

5. Contribution of professional societies.

If institutions, particularly colleges and universities, are to effectively introduce computers into teaching and learning activities, professors must feel they have the support of their departments and administration. A favorable attitude toward effectiveness may be achieved through reviewing activities and other programs of professional societies.

6. The role of publisher and manufacturer.

The trust and cooperation necessary between educators and manufacturers is difficult to achieve since the educator's open environment and tradition of free exchange of data are contrasted with the manufacturer's concern for protecting proprietary information and/or not releasing defective products too early. Cooperation between universities and industry in the production of programs is almost essential. Of course, the major responsibility for what is offered will continue to be with the publisher and author rather than with hardware manufacturers.

7. Rotation of personnel.

When possible, prospective personnel for a project planned at one site should work for a time at another site which is already operational. Furthermore, the start up of the new project should be aided by short-term participation of personnel selected from the other site where the regular staff received some training. The new site in turn will help other schools and colleges to establish new activities in the computer-related area. A chain for communication of experiences then branches out like a tree.

8. Mobile team of experts.

Ideally, a government agency or foundation concerned about economical and effective establishment of new projects at many sites (schools and colleges) would help establish a team of experts which could move from place to place, carrying the experience from one high school or community college to another (along with persons who move from a training site to their home institution as indicated in guideline #6).

9. Demonstration facilities.

A few sample programs, demonstration systems and portable terminals should be available for trial use by any institution considering the establishment of a new program. Complete resources could be installed temporarily at the site including consultants available locally; or persons from the institution should be able to go to another institution or a regional demonstration center for training, trial use and materials development.

10. Source of information and consultation.

A non-commercial clearinghouse could complement the work done by profit-making ventures to provide materials and programs, information about equipment and software, etc. This clearinghouse or national information center would maintain a list of sources of information and service, including individual consultants perhaps available at minimum cost through the service programs of professional societies (e.g., ACM and AERA). It should coordinate efforts with similar centers in other countries through international organizations such as IFIP, Unesco and OECD.

11. Conferences on computers in education.

Regular conferences should be held, some of them quite general and others specific to areas of teaching and to components of the technology. All levels and kinds of education should be represented: elementary, secondary, college, technical, professional, on-campus, and extended education in the home or place of work. Participants should include students as well as teachers in the relevant disciplines, and also potential employers, union officials, agency representatives and others who may be served by education and training involving computers.

12. Roster for international exchange.

A file of resumes and job descriptions should be circulated to encourage bringing expert staff from other countries who wish to spend some time in the U.S. and to increase opportunities for U.S. projects' staff to study abroad.

F. REFERENCES TO RELATED GUIDELINES AND RECOMMENDATIONS

"Guidelines for Instructional Use of Computers" from a Unesco Consultation on Computer Assisted Instruction, Paris, 16-18 March 1970. EDS/MMT/Cons. CAI-TM. This list of guidelines for instructional use of computers with special relevance to developing countries was prepared for Unesco officers, experts and consultants who will be involved in future years in instructional projects with computer components. An adaptation of the preliminary report appeared in the April 1970 issue of the ACM Bulletin on Computer Uses in Education.

"Conference Recommendations" from the IFIP World Conference on Computer Education, Amsterdam, 24-28 August 1970. Nine selected recommendations were reviewed in plenary session 28 August 1970, and revised by the Recommendations Committee 29 August 1970. The copy has been published in a number of places; in the U.S. the convenient source is the ACM Bulletin on Computer Uses in Education, October 1970, which also includes comment on that conference.

"Report of the Final Meeting Held on 21 March 1970" from a Conference on the Use of Computers in Higher Education. Centre for Educational Research and Innovation, OECD. Paris, 19-21 March 1970. CERI/CT/70.37. The summary document was circulated for information only on a restricted basis. Many of the papers from the meeting are available from OECD.

Report of the International Seminar on the Use of Computers in Higher Education, Portland, Oregon, 26-30 October 1970. Summary of discussion and list of recommendations is being assembled by the Northwest Regional Educational Laboratory for distribution early in 1971 by the Centre for Educational Research and Innovation of OECD.

"Significance and Objectives of Computer Science in Secondary Schools." Report of a seminar on Computer Services in Secondary Education held at Sevres, 9-14 March 1970. Centre for Education Research and Innovation, OECD. The summary and final recommendations were distributed by OECD for information on a restricted basis. Excerpts relevant to computers in the instructional process appeared in the April issue of the ACM Bulletin on Computer Uses in Education. The full report was published in Computer Education, No. 5, June 1970, in the United Kingdom.

"Computer Contributions to Learning and Performance: An Outline" from four concurrent discussions on the computer's role in learning, November 20 at FJCC 1969. The intended product was an improved outline for guidance of individual writers preparing the special program materials for the ACM annual meeting in September 1970. Copy appeared in the February 1970 issue of the ACM Bulletin on Computer Uses in Education.

"Computers in Education: Mechanizing Humans or Humanizing Machines." A panel discussion and workshop at SJCC 70, Atlantic City, May 6-7, 1970. A preliminary report appeared in the June 1970 issue of the ACM Bulletin on Computer Uses in Education. Advance notes for the workshop appeared in the April issue, and a complete report is being assembled for publication early in 1971.

"Recommendations for Action" derived from the subsector on the instructional process of the ACM annual meeting, New York City, 2-4 September 1970. Suggestions for further discussion and possible action by ACM members appear in two parts in the October issue of the Bulletin on Computer Uses in Education. Background statements for the session appeared in the August issue. The complete proceedings of the Education Sector of the ACM meeting is in preparation for publication about the middle of 1971.

Proceedings of a Seminar on Computer Based Learning Systems, Leeds University, 5-10 September 1969. The proceedings was edited by John Annett and John Duke, and published by the seminar organizer, the National Council for Educational Technology, London, 1970. The report records five days of presentation and discussion on the role of computers in education. Copies may be ordered from Books for Schools Limited, Councils and Education Press Ltd., 10 Queen Anne Street, London WIM 9LD.

VOLUME I - APPENDIX A

GUIDE TO INFORMATION SOURCES

Brief descriptions are arranged for quick identification of a source for general information about computer contributions, instructional technology and administrative matters, or a source for applications within a specific subject area such as music, mathematics or medicine. To facilitate browsing as well as direct search, the appendix is divided into four sections.

1. Literature Surveys, Reviews and Bibliographies 2

   (Brief annotations of about 30 items arranged alphabetically by author; a list of general sources for the educational administrator or teacher; background material for a researcher or student.)

2. Meetings, Conferences and Symposia (1961 - 1970) 7

   (Selection of about 35 meetings noted in chronological order to indicate the development of this means of exchange of information, and to suggest new sessions which may be useful; also a guide to proceedings and background papers which supplement those publications listed in Section 1.)

   Bibliography for Sections 1 and 2 13

3. Professional Organizations, Publishers, and Commercial Information Services 18

   (Names and addresses of about 35 organizations with brief description of the nature and frequency of their publications or workshops and charges; indication of the number and variety of periodicals available; basis for selection of periodicals by individual readers.)

   Summary of Periodicals 27

   (About 25 publications arranged by the major user audience (computer, education, psychology, administration) and labelled by type (newsletter, bulletin, magazine, journal); suggests areas for new publications.)

4. Publications and Planning Groups Oriented to Various Subject Areas 29

   (Sampling of information sources in about 30 subject areas grouped by humanities, behavioral and social sciences, mathematics and physical sciences, and professions; indicates the extent of computer-related activity in some discipline-oriented organizations; suggests a starting point for locating information on the instructional use of computers within each field.)

The set of information sources in this appendix is not complete and some errors may exist in the brief descriptions; current and complete information should be obtained from the organizations listed.

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1. LITERATURE SURVEYS, REVIEWS AND BIBLIOGRAPHIES

There are many ways to organize information about computer-based instruction systems: student levels, subject areas, learning strategies, hardware systems, programming languages, computer functions, and user purposes. Nearly all of these arrangements are represented in the following sample of surveys and reviews arranged alphabetically by author. Complete references are given in the bibliography at the end of this appendix.

O. Dennis Barnes selected 113 articles and other works from over 40 journals to include in "A Computer Assisted Instruction Annotated Bibliography" citing documentation of systems, programs and research activities. It was published by Phi Delta Kappa, Inc., Bloomington, Indiana, in September 1968.

Don Bushnell, R. de Mille, and J. Purl collaborated on "Educational Implications of Technological Change," Vol. IV, A Report Prepared for the National Commission on Technology, Automation and Economic Progress, February 1966. Published by U. S. Government Printing Office in 1967.

The Commission on Instructional Technology, appointed in March 1968, issued a report in March 1970 entitled "To Improve Learning: A Report to the President and the Congress of the United States." The Commission was concerned with all aspects of instructional technology; its report makes recommendations and suggests priorities for federal involvement in instructional technology. It is available from the U. S. Government Printing Office at $.50 per copy.

A bibliography and KWIC index was published by Gerald Engel in 1967 and revised in 1968 and 1969 (Programming Systems Branch, USNWL, Dahlgren, Virginia 22448). A third revision is currently in progress and publication is expected by the end of 1970. It will again be available through USNWL.

John Feldhusen presented interpretive reviews of recent developments in an article in Educational Technology and a longer one in Contemporary Education, both published in April 1969. A position paper on CAI Research and Development was issued as a Series Two Paper from ERIC in February 1970. Available from the Institute for Communication research, Stanford, California 94305.

Wallace Feurzeig made a survey of instructional uses of computers with examples for the Kettering Foundation entitled "Education Potentials of Computer Technology," 1968, Bolt Beranek and Newman. Defense Documentation Center #1672.

J. Ronald Gentile circulated a review in 1966 which appeared in Audiovisual Communications Review, Spring 1967. After a brief history he discusses the semantic problem of programmed content and strategy, author language convenience, system capability and the effectiveness problem for instructional materials.

A chapter by Duncan Hansen in the Review of Educational Research, December 1966, describes psychological experimentation and simulation as well as different applications of computer-assisted instruction. It gives particular attention to research studies (which have been few).

Albert Hickey and John M. Newton published a survey of the literature in 1966, 1967 and again in 1968, drawn from the files of the Entelek indexing and abstracting service. The October 1968 version is rather comprehensive and gives appropriate attention to research reports and documentation of instructional materials which have been prepared. Through Entelek, Hickey also publishes the CAI Guide.

Donald Holznagel publishes periodically a Computer Education Resource Catalog for the Computer Instruction NETWORK, 4924 River Road North, Salem, Oregon 97303. The catalog includes a serial bibliographic listing of books, pamphlets and periodicals in general categories according to their major content or purpose, an annotation of some works, and a listing of films and reviews.

Max Jerman prepared a report on "Characteristics of CAI Configurations from an Author's Viewpoint" which discusses the capabilities and limitations of existing CAI system hardware, particularly terminal devices for instructional use. The report was given at a conference in September 1968 arranged by the National Council of Teachers of Mathematics and Penn State University, and published in Computer Assisted Instruction and the Teaching of Mathematics (NCTM, 1969).

Manfred Kochen wrote a survey of "Information Science and Computer Aids in Education," for the 6th Annual Colloquium on Information Retrieval, Medical Documents Service, Philadelphia, May 1969. He describes current progress in three inter-related areas: computer-aided instruction, computer-aided question answering and computer-aided information retrieval. The paper appears on pages 209-220 of the colloquium proceedings, The Information Bazaar, edited by L. Schultz.

Roger Levien (RAND Corporation, Santa Monica, California) is conducting a study of the prospects for computer-assisted instruction in higher education for the Kerr Commission on Higher Education. The final report to be available in the fall of 1970 will review current trends for instructional use of computers and suggest guidelines for achieving appropriate use in college instruction.

Andrew Molnar and Beverly Sherman have compiled U.S. Office of Education Support of Computer Activities, a volume of reports, project abstracts, and six appendices related to O.E.support of computer activities in instruction and research. U.S. Government Printing Office, Washington, D. C., 1969. A five-page summary of the report appears in the April 1969 issue of Educational Technology.

Robert Morgan reviewed the state of the art for ERIC at Stanford with special attention to management applications of the computer in secondary education. His report, entitled A Review of Educational Applications of the Computer, Including those in Instruction, Administration and Guidance, appeared in 1969 and copies are available from ERIC, Institute for Communications Research, Stanford, California 94305.

John R. Pierce was Chairman of the Panel which prepared Computers in Higher Education: Report of the President's Science Advisory Committee (U. S. Government Printing Office, Washington, D. C., February 1967). The report provides general recommendations for computer use for teaching and student research in all curriculum areas.

A text by Leonard C. Silvern reviews equipment, systems and strategies along with a presentation of his approach to course development, production and tryout. Entitled Systems Engineering of Education VI: Principles of Computer-Assisted Instruction Systems, it was published in 1970 by Education and Training Consultants Company, Box 49899, Los Angeles, California 90049.

Lawrence M. Stolurow wrote on "Computer Assisted Instruction" for *The Schools and the Challenge of Innovation* (McGraw-Hill and the Committee for Economic Development, 1969). In this chapter he elaborates on the various purposes and unique instructional modes or applications of CAI, the special advantages of a CAI system, and the overall financial costs of computer-assisted instruction.

A book by William R. Uttal, *Real-Time Computers: Technique and Applications in the Psychological Sciences*, (Harper and Row, 1967) includes a chapter titled "Computer Teaching Machines." In his discussion of psychological foundations and of types of computer teaching machines, Uttal emphasizes the unique contributions automated information processing systems can make by automatic generation of the steps in a sequence of instruction. In a forthcoming book which will be published by ENTELEK in 1971, hw expands on his ideas for "generative" computer-assisted instruction (Uttal *et al*., in press).

John F. Vinsonhaler at the Computing Center of Michigan State University maintains under the sponsorship of MICIS (Michigan Inter-university Committee on Information Systems) a computer-based file of an annotated bibliography on computers in education, printing new editions on demand.

John R. Whinnery is chairman of the Instructional Technology Committee of the National Academy of Engineering's Commission on Education which published *Educational Technology in Higher Education: The Promises and Limitations of ITV and CAI*, September 1969. The report provides an overview of the field and discusses the promise of educational technology, problems of higher education, the prospects of future funding and the role of engineering schools in the development of educational technology. It may be obtained free of charge from the Commission on Education, National Academy of Engineering, 2101 Constitution Avenue, N. W., Washington, D. C. 20418.

In a review circulated in 1965 and published in *The Computer in American Education* (John Wiley, 1967), Karl L. Zinn described computer contributions to communication among student, teacher, and author in an instructional system.

Zinn is director of Project CLUE (Computer Learning Under Evaluation), funded by the Office of Education, which is making a critical study of the technology, applications, cost effectiveness and trends for uses of computers in instruction at all levels of education. The final report is scheduled to be completed in December 1970.

In February 1969, Zinn prepared "A Comparative Study of Languages for Programming Interactive Uses of Computers in Instruction," which is available from EDUCOM, 100 Charles River Plaza, Boston, Massachusetts 02114.

The Second Edition of "A Guide to the Literature on Interactive Use of Computers for Instruction" has been prepared by Karl Zinn and Susan McClintock. Issued by ERIC in January 1970, it describes various uses of computers in instruction, types of lessons, systems and computer languages, existing literature surveys, meetings, conferences and symposia which have been held, professional organizations, publishers and commercial information services, a glossary of common terms and a list of individuals responsible for development and demonstration projects. It is available free of charge from the ERIC Clearinghouse, Stanford University, Stanford, California 94305.

2. MEETINGS, CONFERENCES AND SYMPOSIA (1961-1970)

The sources which follow are organized chronologically by date of occurrence. In addition to the publications and proceedings which were an outcome of the meetings held, the references may also assist the reader by suggesting where to look for materials resulting from meetings or conferences to be held in the next year or so. Regularly scheduled conferences (FJCC, SJCC, AERA, AEDS, and ACM) are held annually or bi-annually and generally have conference proceedings available (see Section 3).

John Coulson of System Development Corporation (SDC) edited the proceedings of the October 1961 Conference on Application of Digital Computers to Automated Instruction, sponsored by SDC and the Office of Naval Research. The proceedings were published in a book entitled Programmed Learning and Computer-Based Instruction (John Wiley, 1962).

A conference was sponsored by AEDS and Stanford University on uses of computers in American education in October of 1965. Sections of two of the presentations appeared in Saturday Review 1966 and the conference report The Computer in American Education was edited by Don D. Bushnell and Dwight W. Allen and published by John Wiley in 1967.

A conference on the Computer in American Universities was held at the University of California at Irvine in November 1965. The contributed papers were published in 1967 with a transcript of discussion (Computers and Education, edited by Ralph Gerard, McGraw-Hill).

The Commission on College Physics (CCP) also sponsored a conference in November 1965, at Irvine. The report of that working session, The Computer in Physics Instruction, is no longer available from the Commission at the University of Maryland. It will be replaced by a greatly expanded Conference Report of the Conference on Computers in Undergraduate Science Education sponsored jointly by the CCP and the Illinois Institute of Technology, to be held in Chicago in August 1970. The purpose of the second conference is to consolidate the body of existing knowledge on the uses of computers in education,particularly in physics and mathematics, and to aid in the dissemination of knowledge regarding recent advances. For information contact Ronald Blum, CCP, 4321 Hartwick Road, College Park, Maryland 20740.

In March 1966, the Office of Naval Research CAI interest group met in Cambridge at Bolt Beranek and Newman and at Harvard University Computation Center. (ONR supported many of the innovative projects in this area, and through Entelek, encouraged meetings to exchange information.) Participants discussed CAI languages for both students and authors. A summary was distributed by Entelek and appeared in Automated Education Letter. In July 1966, Educom established an informal working group in the area of author languages.

Also during July 1966, Educom assembled a number of experts and representatives from member institutions to discuss and plan a network for communication among colleges and universities in North America. The report of that conference detailed designs and projections of need and probable uses for network services. The report was edited by Brown, Miller and Keenan, and published in July 1967 by John Wiley under the title EDUNET.

In August of 1966 and 1967, educational technology and special equipment were described and demonstrated at a conference of the American Management Association (AMA), 135 W. 50th, New York, N.Y. 10020. The conference programs describe topics and participants; no summary of the sessions has been published. AMA Conferences on Education and Training were held in August 1968 and 1969.

The ONR CAI interest group met at System Development Corporation, Santa Monica, California, in September 1966. Various SDC programs exploring computer aids in educational systems were described, and participants discussed issues related to successful implementation of CAI. A summary of these sessions is available from Entelek; sections of the summary appeared in Automated Education Letter, January and February 1967.

A conference on computer assisted testing was held November 1966. Proceedings entitled "Computer Assisted Testing, Proceedings of a Conference" were edited by Harmon, Helm and Loye at Educational Testing Service, Princeton, New Jersey.

The ONR CAI interest group met at Pennsylvania State University in April 1967. Research and development activity in technical education using an IBM 1410 and experimental Coursewriter was described. A summary was distributed by Entelek.

The Education Policy Project at George Washington University conducted a "traveling seminar" for the Office of Education during July of 1967. The background papers, briefing sessions and conclusions of the seminar participants are presented in the final report titled Education in the 70's. Copies are available from the ERIC Document Reproduction Service, which lists it as document ED 022 361.

An NSF-sponsored conference, Computers in Undergraduate Education: Mathematics, Physics, Statistics, and Chemistry, was held in December 1967. Panels of university faculty were formed in each discipline to discuss their views on the impact which they believed computers would have on their undergraduate programs and to make recommendations for future NSF activities. The panel reports and related discussions appear in the proceedings which may be obtained from the Office of Computing Activities, National Science Foundation, 1800 G Street, N. W., Washington, D. C. 20550.

An ONR interest group on simulation in instruction met at The University of Texas at Austin, January 1968. Special attention was given to projects of the CAI Lab at Texas and the simulations for testing and training at the Manned Spacecraft Center in Houston. Notes have been distributed by Entelek.

A conference on the Use of Computers in Medical Education was held at the University of Oklahoma Medical Center in April 1968. Sessions considered computers in undergraduate, clinical, and continuing education, as well as their use in medical libraries. The conference proceedings are available from the University of Oklahoma Medical Center, 800 N. E. 13th Street, Oklahoma City, Oklahoma 73104.

NATO sponsored a conference on computers and learning in Nice, France, in May 1968. No official proceedings are available, but informal proceedings were distributed by the U. S. Office of Naval Research.

Under sponsorship of the National Science Foundation's Office of Computing Activities, Stanford University, and the University of Illinois, a working conference on systems design for computer-based instruction was held in Colorado in June 1968. Emphasis was directed at discussion of hardware systems (design objectives and criteria), and at languages, teaching strategies, and software for CBI systems. Notes of the conference are available from Dean Daniel Alpert, University of Illinois, Urbana.

Pennsylvania State University held a conference on Computers in Mathematics education in September 1968. The proceedings (edited by Ralph Heimer and published by the National Council of Teachers of Mathematics, Inc., 1969) included summary chapters by Max Jerman and Karl L. Zinn (see Section 1).

William Viavant edited Computers in Undergraduate Education (Volumes I and II) as the proceedings of a conference in Park City, Utah, September 1968. Published by the University of Utah in 1969, the work includes reports from federal agencies, the programs of the NSF, and transcripts of a set of workshops on curriculum and programs, computers in engineering and science education, the social behavioral sciences and humanities, facilities and resources and computers in the liberal arts college.

A conference on Computer-Assisted Instruction, Testing and Guidance at the University of Texas, October 1968 was sponsored by Educational Testing Service and the Social Science Research Council. Specialists discussed the latest research and theoretical developments, the state of computer-based technology, and problems related to the implementation of such technology. Proceedings edited by Wayne Holtzman are in press for publication by Harper and Row, 1970.

At a conference on Instructional Strategies Appropriate to Computer-Assisted Instruction in Washington, D. C., October 1968 experts discussed the classification and significance of instructional strategies and operational definitions of individual strategies. Proceedings were edited by Albert Hickey and published by Entelek as ONR Technical Report No. 9.

The New York State Conference on Instructional Uses of the Computer took place October 3-5, 1968, at Sterling Forest Conference Center, Tuxedo Park, New York 10987. The final report was published in 1968 by New York State Education Department and Northern Westchester BOCES, Yorktown Heights, N.Y., 1968.

EDUCOM, in conjunction with the University of New Hampshire and with the assistance of the National Science Foundation, staged a symposium entitled The Computer Utility -- Implications for Higher Education held in Manchester, New Hampshire, May 1969. A summary of the symposium's recommendations can be found in the September 1969 issue of EDUCOM, The Bulletin of the Interuniversity Communications Council, Inc. (Volume 4, Number 3). The papers presented at the symposium have been incorporated into a volume of the same name to be published in August 1970 by D. C. Heath & Co., 125 Spring Street, Lexington, Massachusetts 02137. Editors are Michael Duggan, Edward McCartan and Manley Irwin.

In September 1969, the National Council for Educational Technology, 160 Great Portland Street, London W1, held a symposium at the University of Leeds on Computer Based Learning Systems. Proceedings having the same title were published in 1970 and are available from Books for Schools Limited, Councils and Education Press Ltd., 10 Queen Anne Street, London WIM 9LD. NCET working papers and a feasibility study for a program for research and development were published in 1969 and are available from the Council offices.

A Conference on Computer Applications in Dental Education was held in San Francisco, October 1969, sponsored by the Professional Education Branch, Division of Dental Health of the National Institutes of Health. A summary of the conference can be obtained by writing to Dr. Luigi Lucaccini, Professional Education Branch of the Dental Health Center, 14th Ave. and Lake Street, San Francisco, California 94118.

The Second Annual National Laboratory for the Advancement of Education was held in Washington, D. C., January 26-28, 1970. It was sponsored by The Aerospace Education Foundation and the U. S. Office of Education.

The Centre for Educational Research and Innovation (CERI) of the Organization for Economic Co-operation and Development (OECD) held two international seminars in Paris, France, in March 1970. The first, Computer Sciences in Secondary Education, was called to discuss and make recommendations for the possible content of a curriculum for this subject and the methods appropriate to teaching it. The second seminar, Computers in Higher Education, was held to consider CAI and other computer uses in college curricula, and did not make specific recommendations. The papers and discussion summaries of both sessions should be available soon from OECD-CERI, 2 rue Andre Pascal, Paris.

A symposium on Biomathematics and Computer Sciences in the Life Sciences was held in Houston, Texas, March 23-25, 1970, to inform investigators of research and applications of biomathematics, computer science, and bioengineering in the life sciences and to provide a forum for the exchange of ideas concerning new research and applications.

The Computers and Design Conference was held April 20-22, 1970, at the University of Kentucky in Lexington to examine the effect that high speed information handling equipment has had upon the environmental design profession. Proceedings should be available early in 1971. For information, contact Michael Kennedy, Chairman, Conference Committee, School of Architecture, Pence Hall, University of Kentucky, Lexington, Kentucky 40606.

A conference on Computers in the Undergraduate Curricula was held at the University of Iowa in June 1970 with financial support from the National Science Foundation. The goal was to provide a national forum for the presentation, discussion and dissemination of ideas, programs and other curricular materials dealing with the use of a computer in undergraduate education and to assess the needs for a continuing national forum for study of computer use in undergraduate curricula. Preliminary Proceedings were distributed at the Conference; information about the final proceedings may be obtained from G. P. Weeg, Director, Iowa Regional Computer Center, W 17 East Hall, University of Iowa, Iowa City, Iowa 52240.

The Michigan Department of Education and the INDICOM Project sponsored a conference on Computer Applications to Learning July 8-10, 1970, in order to provide educational administrators with basic facts concerning applications of computer technology to administrative and instructional problems. For information on proceedings contact INDICOM Project, 1325 Crescent Lake Road, Pontiac, Michigan 48054.

In August 1970, the Commission on College Physics and the Illinois Institute of Technology held a Conference on Undergraduate Science Education. The prupose is to consolidate the body of existing knowledge on the uses of computers in education, particularly in physics and math, and to aid in the dissemination of knowledge regarding recent advances. It will replace the proceedings of the 1965 conference (see page 7). For information contact Ronald Blum, CCP 4321 Hartwick, College Park, Maryland 20740.

The International Federation for Information Processing (IFIP) held World Conference on Computer Education in Amsterdam, The Netherlands, in August of 1970. Three plenary sessions on current developments in computer education, educational technology and the impact of computers on society and education were followed by corresponding workshops and round table discussions. Preliminary proceedings were distributed at the Conference and a final proceedings, including some record of discussion and recommendations, will be published shortly afterwards. For information contact A. A. M. Veenhuis, Stadhouderskade 6, Amsterdam, The Netherlands.

The ACM annual meeting September 1 through 4 included a number of sessions on education and computers, ranging from graduate education programs to computer literacy for all, and from consideration of open-ended problem-solving environments to strictly controlled, automated tutorials. The proceedings of the conference will lead to further writing and dissemination in connection with a major effort by ACM during 1970-71 to provide information and interpretation useful for end users. Information is available in the June issue of the ACM Special Interest Group Bulletin on computer uses in education and from ACM Headquarters, 1133 Avenue of the Americas, New York, N. Y. 10036.

The Eleventh Annual IEEE Symposium on Man-Machine Systems was held in Winter Park, Florida, November 12-13, 1970. Members at the meeting were to assess the role of engineering systems in the changing world of education and training and project the role of such systems in future education and training. For information on publications, contact S. E. Michaels, Bell Telephone Laboratories, Room 3D-529, Holmdel, New Jersey 07733.

An Invitational Conference on "Computers in Instruction: Their Future for Higher Education" was sponsored by the National Science Foundation, the Carnegie Commission on Higher Education, The Rand Corporation, and the Department of System Science, University of California, Los Angeles. It was held October 1-3, 1970, at the University of California, Los Angeles, and meetings concerned computer capabilities and costs, the provision of computer services and instructional materials on campuses, and future changes in educational institutions.

An Invitational Conference on "Computers in Higher Education" was sponsored by the Center for Educational Research and Innovation of OECD and the Northwest Regional Educational Laboratory at Portland, Oregon in October of 1970. Specialists in instructional computer use from Europe, Japan and the United States collaborated on a set of guidelines and recommendations for potential computer uses in educational systems throughout the world. A report of the conference is in preparation.

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3. PROFESSIONAL ORGANIZATIONS, PUBLISHERS AND COMMERCIAL INFORMATION SERVICES

Publishers and professional organizations which periodically publish materials relevant to interactive uses of computers in education are listed along with commercial information services which sponsor workshops, issue newsletters and sometimes provide computing services. Following the descriptive portion, a table summarizes the periodicals.

Academic Press Incorporated, Berkeley Square House, Berkeley Square, London, W 1, England, and 111 Fifth Avenue, New York, N. Y. 10003. Since January 1969, the *International Journal of Man Machine Studies* has been published quarterly. The content includes instructional use of computers along with man-machine interaction, the man-machine interface, mathematical and engineering approaches to the study of man and biological approaches to the development of machines. Dr. G. B. B. Chaplin is editor (140 s or $7.00 per year).

American Educational Research Association (AERA), 1201 16th Street, N. W., Washington, D. C. 20036. Richard A. Dershimer, Executive Officer. *The Educational Researcher* is the official newsletter of the Association and is published about seven times a year. Currently edited by W. C. Wolf, Jr., at 22 Mt. Pleasant, Amherst, Massachusetts 01002, the newsletter notes meetings, new federal programs and the initiation of major research projects. ($2.50 per year).

The *American Educational Research Journal*, published quarterly ($8.00 per year) frequently carries articles related to computers in education. Material can be sent to the editor, Richard L. Turner, at the School of Education, Room 229, Indiana University, Bloomington, Indiana 47401.

The *Review of Educational Research* includes in its five issues per year two or three chapters on educational technology and computers ($10.00 per year). The editor is Gene V. Glass, Laboratory of Educational Research, University of Colorado, Boulder, Colorado 80302.

The annual AERA meeting in February is likely to include reports of current research and development. Special sessions are arranged by the Special Interest Group on Computer Aids to Instruction (SIGCAI) under the chairmanship of John Coulson, Public Systems Division, System Development Corporation, Santa Monica, California 90406.

American Federation of Information Processing Societies (AFIPS), 211 E. 43rd Street, New York, N. Y. 10017. The Fall Joint Computer Conference (FJCC) and Spring Joint Computer Conference (SJCC) include sessions relevant to instruction, but often under such headings as system design, programming languages, and natural language processing, as well as under computer-assisted instruction. The Conference Proceedings of FJCC and SJCC are published by the AFIPS Press at the time of the meetings (usually November and April); before 1969, proceedings were published by Thompson, Spartan and others.

American Psychological Association (APA), 1200 Seventeenth Street, N. W., Washington, D. C. 20036. Educational Psychologist is the official newsletter of Division 15 (Educational Psychology) and is published three or four times a year. Correspondence and contributions should be directed to Richard E. Ripple, Editor, Division of Educational Psychology, Stone Hall, Cornell University, Ithaca, New York 14850. Subscriptions are $1.00 per academic year.

The Journal of Educational Psychology is a bi-monthly publication which includes articles and reports associated with problems of learning and teaching ($10.00 per year). Manuscripts and correspondence on editorial matters should be sent to Wayne H. Holtzman, Editor, University of Texas, Austin, Texas 78710.

Association for Computing Machinery (ACM), 1133 Avenue of the Americas, New York, N. Y. 10036. A number of the monthly issues of Communications of the ACM include articles on use of computers for instruction. Often these are concerned with the training of computer programmers, technicians and users. The Education Editor is Peter Wegner, Department of Applied Mathematics, Brown University, Providence, Rhode Island 02912. Sections on programming languages and computational linguistics occasionally are relevant to instructional programs ($20.00 per year).

The Journal of the ACM includes relevant material only occasionally, but issues of Computing Reviews frequently have abstracts of technical reports and papers from projects using computers for instruction.

Computing Surveys began publishing quarterly in March 1969 as the survey and tutorial journal of the ACM ($7.00).

The Association has a Special Interest Group on Computer Uses in Education; the current chairman is Karl L. Zinn, 1315 Hill Street, Ann Arbor, Michigan 48104. A bulletin, Interface, is issued five times a year with membership at $4.00 per year. It contains technical reports, material on the technical programs of ACM, and information about special meetings and workshops in the field of computers and education. The group also plans sessions for meetings of ACM (August) and AFIPS (usually November and April). The Association has numerous other Special Interest Groups and Committees which may be found under the specific discipline in the next section.

Association for the Development of Instructional Systems (ADIS), C. Victor Bunderson, Chairman, CAI Laboratory, Sutton Hall, University of Texas, Austin, Texas 78721, and Helen Lekan, Secretary-Treasurer and Newsletter Editor, Instructional Media Laboratory, University of Wisconsin - Milwaukee, Milwaukee, Wisconsin 53201. ADIS Newsletter, issued monthly, provides for the exchange of system programs and instructional materials among its members ($6.00 per year). The Association, which meets twice a year, started as a group of IBM 1500 System users. While it is now open to users of any CAI equipment, most members are IBM users interested in Coursewriter and APL.

Association for Educational Data Systems (AEDS), 1201 Sixteenth Street, N. W., Washington, D. C. 20036. AEDS Monitor, the magazine of the Association, is published 11 times each year; most material has been on data processing ($15.00 per year). Material for publication should be sent to Dean D. Crocker at the Iowa Department of Public Instruction, Des Moines, Iowa 50319.

The Journal of the Association of Educational Data Systems, published four times each year, includes many articles on computers and education ($10.00 per year). Bruce Alcorn is editor.

The annual meeting of the Association in March or April always includes sessions on computers and instruction. A series of workshops on educational data processing held at various locations during 1967-68 included sessions on CAI; proceedings are available from AEDS.

Automated Education Center, P. O. Box 2658, Detroit, Michigan 48231. Frank H. Gille, Publisher. The Automated Education Handbook ($35.00) and a newsletter Automated Education ($18.00 per year) provide information about programmed instruction, audio and visual media, and computer assistance. Most of the material in the newsletter is selected from news releases and other publications for potential educational users of computers. The Handbook includes research reports, discussion of procedures, and summaries of technology and applications. AEC recently started a monograph series reprinting technical reports and tutorial materials.

Berkeley Enterprises, 815 Washington Street, Newtonville, Massachusetts 02160. Edmund C. Berkeley, Editor and Publisher. Computers and Automation is a monthly journal; articles are usually informal and descriptive. Sometimes information about a new project appears here before it is reported more formally. Usually each March issue carries a set of articles on "Computers and Education" ($15.00 per year). Berkeley also publishes books and monographs bearing on computers in education.

Berkeley and Computers and Automation operate and maintain a PDP-9 computer (made by Digital Equipment Corporation) using more than half a dozen interactive programming languages, including LISP, FOCAL, DDT, and EXPL. One of the main purposes of this installation is research and investigation in learner-controlled computer-assisted instruction.

Computer-assisted Instruction, Inc. (CAI, Inc.), 111 West Monroe Street, Chicago, Illinois 60603, Dr. Robert C. Kyle, President. CAI, Inc. specializes in design, development and implementation of training systems. One-day seminars directed to business, industry, government and schools consider the present and future potential for use of computers in the educational and training process. Subscription fees vary.

Computer Decisions. See Hayden Publishing Company.

Computers and Automation. See Berkeley Enterprises.

Computer Education Group, an affiliate of the British Computer Society and Schools Council Project Technology, c/o Chairman, North Staffordshire Polytechnic, Department of Mathematics, Science & Computing, Beaconside, Stafford, England. The two organizations collaborate in the publication of the quarterly bulletin, Computer Education. Originally intended for readers in the United Kingdom, recent issues have increasing relevance for an international audience. The editor is B. Bowker, Enfield College of Technology, Queensway, Enfield, Middlesex, England.

Datamation. See Technical Publishing Company.

Data Processing for Education, 1309 Cherry Street, Philadelphia, Pennsylvania 19107 is a monthly newsletter (formerly published by the Automated Education Center). It discusses current and projected programs and publications in the field of computers in education of both national and international scope ($36.00 per year).

Data Processing Magazine. See North American Publishing Company.

Educational Data Processing, Journal of. See Educational Systems Corporation.

Educational Systems Corporation, Dr. Murray Tondow, President, Stanford P.O. Box 2995, Stanford, California 94305. This non-profit group publishes the Journal of Educational Data Processing (quarterly), including articles on uses of computers for instruction, especially for the teaching of programmers and technicians. The Fall 1967, Spring 1969 and Summer 1970 issues are devoted to CAI. Alvin Grossman is editor ($9.00 per year).

Educational Technology, Journal of. See National Council for Educational Technology.

Educational Technology Publications, Inc., 140 Sylvan Avenue, Englewood Cliffs, New Jersey 07632, publishes books and monographs on the educational use of computers as well as the monthly periodical, Educational Technology, which has one or more articles or notes on instructional use of computers in each issue. The March 1970 issue is devoted to "The Computer and Education." Lawrence Lipsitz is editor ($18.00 per year).

EDUCOM (Interuniversity Communications Council, Inc.), Box 364, Princeton, New Jersey, 08543. Henry Chauncey, President. The central office distributes a bi-monthly publication, EDUCOM, The Bulletin of the Interuniversity Communications Council, without charge to the faculty of its 105 member institutions of higher education. The Bulletin is also available on a subscription basis at $10 per year or $5 per year to educational institutions.

Needs in the area of computer uses for instruction are reviewed, along with other topics, by panels concerned with technology and applications. A set of documents on programming languages and technical assistance for authors was prepared in cooperation with the Center for Research on Learning and Teaching, University of Michigan. Copies of this comparative study of languages, partially funded by the Office of Naval Research, are available from Educom.

The recently organized Educational Information Network (EIN) is administered by Educom. Funded by USOE and NSF, EIN is developing a pilot network which will assemble directory and information services, recommend standard practices, and facilitate cost sharing of communication circuits and special computer facilities for remote use or for information exchange.

Entelek, Inc., 42 Pleasant Street, Newburyport, Massachusetts 01950. Albert Hickey, President. Entelek conducts a CAI/CMI Information Exchange originally contracted for by ONR which periodically distributes abstracts of CAI and CMI research documents, summaries of operational CAI programs, and descriptions of individual CAI facilities. Five by eight inch data cards are mailed in multiple copies for cross-indexing and are accompanied by author, subject, KWIC, and bibliographic indexes. ONR originally paid the costs for about 60 institutions active in the CAI field and in the exchange; subsidy is no longer necessary and all participants now subscribe at $150 per year. Entelek has proposed a new journal called Computers in Instruction; William R. Uttal would be the editor.

Entelek assists with CAI interest group meetings, publishes summaries, and distributes an occasional newsletter, entitled CAI/CMI Letter. The first three editions of CAI: A Survey of the Literature, based on data in the information exchange, were published 1966, 1967 and October 1968. The fourth edition is in press. Proceedings of the Entelek regional meetings are currently in process and information on them may be obtained by writing to Sally Birch, Entelek.

ERIC Clearinghouse on Educational Media and Technology, Institute for Communication Research, Stanford University, Stanford, California 94305. The current report literature is indexed and abstracted in Research in Education ($21.00 per year, U. S. Government Printing Office, Washington, D. C. 20402), while journal literature is indexed in Current Index to Journals in Education ($34.00 a year, CCM Information Corp., 909 Third Avenue, New York, N. Y. 10022).

Supported by the Office of Education, it has been chartered to collect, review and abstract publications and documents of importance in the various media areas, including computer-assisted instruction, and to prepare them for indexing and storage in a computer-accessed data base. While the Clearinghouse does not collect actual teaching materials, it does prepare and publish summary papers on the state-of-the-art in different parts of the field (see Feldhusen, Morgan and Zinn in Section 1). Documents are available from the ERIC Documents Reproduction Service in Maryland in microfiche or photocopy. ERIC at Stanford's regular newsletter is free upon request.

Education and Training Consultants Co. (ETC), 12121 Wilshire Boulevard, Los Angeles, California 90049 (Mailing: Box 49899, Los Angeles 90049). Dr. Leonard C. Silvern, President. Three-day to two-week training programs in "CAI Systems" and "Advanced CAI Systems" are presented in Los Angeles each February, July and November. The same courses are given at various locations in the United States on a contract basis. This commercial organization publishes technical reports in the Systems Engineering of Education Series, filmstrips, sound-slide presentations, CAI courses and news releases in the area of education, training and systems techniques.

Hayden Publishing Company, Inc., 850 Third Avenue, New York, N. Y. 10022, James S. Mulholland, Jr. President. Computer Decisions is a monthly magazine which includes articles on information systems, automated processing and problem solving. Robert C. Haavind is editor in chief.

The Institute for Advanced Technology (IAT), CEIR Inc., of the Central Data Corporation, 5272 River Road, Washington, D. C. 20016. CEIR holds three-day seminars on Computer Assisted Instruction for those involved in education and training functions. No prior computer knowledge is necessary.

Institute for Computer Assisted Instruction (ICAI), 42 East Court Street, Doylestown, Pennsylvania 18901. Dr. Alex B. Kyle, President. This commercial organization holds a number of conferences, meetings, training workshops for instructional programmers, and public one-day briefings each year. It plans to publish an annual state-of-the-art review and also the CAI Newsletter (8 issues, $12.00 per year).

Institute of Electrical and Electronic Engineers (IEEE), 345 E. 47th Street, New York, N. Y. 10017. Proceedings of the IEEE occasionally is devoted entirely to computers and related subjects. The last such issue was December 1966, which contained some papers on computer-aided instruction. The November 1967 issue was devoted to computer-aided design ($22.00 per year, single copy of special issues $4.00). IEEE Transactions on Man-Machine Systems (name changed from Transactions on Human Factors in Electronics), IEEE Transactions on Education and IEEE Transactions on Systems Science and Cybernetics often include relevant papers. A special issue of the first journal, June 1967, contained eight articles focused on computers and education. Subscription prices vary (single copy $5.00).

Instructional Media Laboratory (IML), University of Wisconsin -- Milwaukee, Milwaukee, Wisconsin 53201. Directed by Robert E. Hoye, the laboratory is primarily concerned with the University of Wisconsin System; nevertheless it prepares an Index to Computer Assisted Instruction now published by Sterling Institute and edited by Helen Lekan (see Lekan, Section 1).

International Federation for Information Processing, 6 Stadhouderskade, Amsterdam 13, The Netherlands; Congress Office, 23 Dorset Square, London N. W. 1, England. Proceedings of the IFIP tri-annual congresses often contain technical papers related to computer applications in education. Proceedings of the 1962, 1965 and 1968 congresses should be available from the North-Holland Publishing Company, P. O. Box 3489, Amsterdam. Special meetings are held occasionally, such as the World Conference on Computer Education in Amsterdam, August 24-28, 1970.

The National Association of Secondary School Principals (NASSP), 1201 16th Street, N. W., Washington, D. C. 20036. During 1970 the Committee on Computers in Education of the NASSP offered a series of seminars on potential uses of the computer in various parts of the country. Co-sponsored by Sterling Institute, the seminars included an explanation and actual use of CAI programs in various curriculum areas, use of the computer in the classroom as a problem-solving tool, exploration of CMI and IPI as well as exposure to and use of new instructional technologies. The seminars are intended primarily for secondary school principals. Registration fees from $115 to $170 for a two and one-half day session.

National Association of Users of Computer Applications to Learning (NAUCAL). Mr. John Grate, Associate Director, Program Research and Design, Cincinnati Public Schools, 320 East 9th Street, Cincinnati, Ohio 45202. This group was organized by large school systems having CAI projects. The initial purpose was to present a defined, unified market to hardware and software vendors interested in CAI. Plans include a centralized dissemination of information on CAI to members.

National Catholic Education Association, 1 Dupont Circle, N. W., Washington, D. C. 20036. The Association publishes a calendar of all national and regular educational meetings each year. Entries give dates, places, tentative agendas, discussants, etc. ($1.80 per year).

National Council for Educational Technology (NCET), 160 Great Portland Street, London, W 1, England. The Journal of Educational Technology is the official publication of the NCET. It began publishing three issues per year in January 1970. The periodical is concerned primarily with the theory, applications and development of educational technology and communications, and includes editorials, research reports and articles. (3£10s per year or $8.40).

National Education Association, 1201 16th Street, N. W., Washington, D. C. 20036. Audiovisual Instruction is published ten times per year by the Department of Audiovisual Instruction (DAVI) of the NEA. Material for publication should be sent to the editor, Ann L. Hyer ($8.00 per year). The Audiovisual Communications Review, published quarterly by DAVI occasionally includes research reports and survey articles ($8.00 per year). DAVI holds an annual conference each spring; the 1971 convention will be held in Philadelphia from March 21 through 26.

National Society for Programmed Instruction, Trinity University, 715 Stadium Drive, San Antonio, Texas 78212. The annual meeting usually is scheduled for April and includes sessions on instructional use of computers. NSPI Journal is the official monthly publication of the Society (not published in January and August). Elaine Davis is managing editor. The journal contains articles on all facets of instructional programming as well as some newsnotes; computers are receiving increasing attention. Annual subscription is $20.00 for non-members; $5.00 for members.

North American Publishing Co., 134 North Thirteenth Street, Philadelphia, Pennsylvania 19107, I. J. Borowsky, President. Data Processing Magazine is a trade journal that appears monthly. It contains a section on the use of computers in education. Martin Nussbaum is editor. ($8.50 per year).

Organization for Economic Co-Operation and Development (OECD), Centre for Educational Research and Innovation (CERI), 2 Rue Andre Pascal, Paris XVIe, France. Originally concerned with economic redevelopment of Western Europe, OECD is now focusing its attention on social and educational problems. CERI is reviewing computers and other technology for educational innovation. The proceedings of meetings held in March 1970 are likely to be available soon.

System Development Corporation, 2500 Colorado Avenue, Santa Monica, California 90406. The SDC Magazine (monthly) occasionally includes articles on uses of computers for instruction, especially uses in systems training projects conducted by System Development Corporation. Available SDC publications are listed each month on the last page of the magazine. Discontinued in 1970.

Technical Publishing Co., 94 South Los Robles Avenue, Pasadena, California 91101, publishes Datamation, edited by Robert B. Forest. This trade journal includes occasional articles on the use of computers in instruction. A special issue on computers and education appeared in September 1968. Subscription inquiries should be directed to Datamation, 35 Mason Street, Greenwich, Connecticut 06830. Issued 24 times per year ($25.00 per year).

SUMMARY TABLE OF PERIODICALS FOR COMPUTERS IN EDUCATION

N - Newsletter: news, announcements, abstracts
B - Bulletin: technical reports, position statements (viewpoints), news
M - Magazine: tutorials, position statements, informal reports, some news
J - Journal: refereed papers (technical reports, research findings, and surveys, reviewed before acceptance for publication)

Each periodical is listed in a column for the audience of computer users and specialists to which it appears to be primarily directed; a secondary audience sometimes is indicated in parentheses in another column.*

C&IP : Computer and information processing scientists and teachers of computer studies
E&IT : Educational and instructional technologists
EP : Educational psychologists
Adm : Administrators

PERIODICAL	C&IP	E&IT	EP	Adm
ACM				
Communications of the ACM	B/J			
Computing Surveys	J			
Bulletin of the Special Interest Group on computer uses in education (INTERFACE)	B	(B)		
Computer Education	B			
Datamation	M			
Computers and Automation	M			
Data Processing Magazine	M			
Computer Decisions	M			

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* Discipline oriented periodicals that contain information on the instructional use of computers such as the Journal of Engineering Education or Computers in the Humanities are not included in this table. They appear in Section 3 which provides information on the educational use of computers in specific disciplines.

PERIODICAL	C&IP	E&IT	EP	Adm
IEEE				
Transactions on Education	J			
Transactions on Systems Science and Cybernetics	J			
Transactions on Man-Machine Systems	J			
International Journal of Man-Machine Studies	J	(J)		
EDUCOM Bulletin	(B)	B		
(Computer Contributions to Learning and Teaching, proposed by Elsevier)	(J)	J	(J)	
ADIS Newsletter	(N)	N		
(Instructional and Learning Science, proposed by Elsevier)	(B)	J		
NEA				
Audiovisual Instruction		M		
Audiovisual Communications Review		J		
Entelek CAI/CMI Letter		N		
(CAI Letter, proposed by the Institute for Computer Assisted Instruction)		N		
Automated Education Letter		N		
Data Processing for Education		N		
Educational Technology		M		
Journal of Educational Technology (NCET)		J		
NSPI Journal		J	(J)	

PERIODICAL	C&IP	E&IT	EP	Adm
AERA				
American Educational Research Journal			J	
Review of Educational Research			J	
Educational Researcher			B	
APA				
Educational Psychologist			B	
Journal of Educational Psychology			J	
AEDS				
Monitor	(B)	(B)		B
Journal of AEDS		(J)		J
Journal of Educational Data Processing (annual special issue)		(J)		J

4. PUBLICATIONS AND PLANNING GROUPS ORIENTED TO VARIOUS SUBJECT AREAS

Information listed in this section specifies professional organizations which provide information or publish materials on the instructional use of computers in their field. Some of these organizations have been extremely active in providing materials and assistance to members wishing to utilize computers in their teaching activities; others are only now realizing the importance of computers and recognizing their responsibility to disseminate information, organize working groups, minimize duplication, etc.

A teacher interested in locating existing computer-based material for use in his course can consult various guides or indices such as those prepared by Entelek and Sterling Institute (see Section 3). However, it would be of considerable advantage to him if there were a library of these materials and annotated listings within his discipline. Ultimately, such libraries should include evaluative critiques to assist the user in selecting the most appropriate materials for his needs. (See also Appendix C of Volume II on recommended programs for professional societies.)

The material in this section does not detail the activities of all professional organizations; rather, it is meant only to indicate the extent of activity within a discipline orientation and the prospects for assistance to individual teachers from this quarter. The section is intended as a preliminary guide to teachers and administrators within each discipline who may be unaware of the specialized assistance available to them.

Contents:

1. Humanities (page 30)
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    d. Literature
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    c. Education
    d. Engineering
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    f. Law
    g. Library Science
    h. Medicine and Dentistry
    i. Social Work
    j. Urban Planning

1. Humanities

   a. General

      1. Organizations

         Special Interest Group on Arts and Humanities
         American Society for Information Sciences (ASIS)
         1140 Connecticut Ave., N.W., Washington D.C. 20036

      2. Publications

         Computers and the Humanities
         Queens College of the City University of New York
         Flushing, New York 11367

         September 1969 issue contains proceedings of a two-day symposium at Queens College, May 9-10, 1969, "Humanities: Computers 69." Specific topics are covered in many other issues and articles, and the sections on "recent publications" and "book reviews" provide many leads to other information

         Computer Studies in the Humanities and Verbal Behavior
         Floyd Horowitz, Editor
         University of Kansas
         Lawrence, Kansas

         Boehm, George A.W., "New Graphics for Arts and Science," Think, March-April 1969, IBM, Armonk, New York 10504

         Bowles, Edmund A. (ed.) Computers in Humanistic Research, Prentice-Hall, Englewood Cliffs, New Jersey, 264 pp., 1967.

         Presents short surveys of the use of computers in different fields of the humanities and social sciences.

         Sedelow, Sally Yeates, "The Computer in the Humanities and Fine Arts," Computing Surveys, Vol. 2, June 1970.

   b. Art

      1. Publication

         Paquette, Russell, "Cybernetic Art: The Computer as Renaissance Man," SDC Magazine, Vol. 12, No. 4, April 1969, System Development Corporation, 2500 Colorado Ave., Santa Monica, California 90406.

   c. Languages and Linguistics

      1. Organizations

         Modern Language Association of America
         62 Fifth Avenue, New York, N. Y. 10011

         ACM Special Interest Group on Language Analysis and Studies in the Humanities (SIGLASH)
         c/o ACM National Headquarters
         1133 Avenue of the Americas, New York, N.Y. 10036
         SIGLASH Bulletin, 5 issues per year

ERIC Clearinghouse on the Teaching of Foreign Languages
Modern Language Association
62 Fifth Avenue
New York, N. Y. 10011

Abstracts of documents on commonly taught languages.

ERIC Clearinghouse on Linguistics
Center for Applied Linguistics
1717 Massachusetts Avenue, N. W.
Washington, D. C. 20036

Abstracts of documents on linguistics and the less-taught languages.

ERIC Clearinghouse on the Teaching of English
National Council of Teachers of English
508 South Sixth Street
Champaign, Illinois 61820

Abstracts of documents on English language and literature.

2. Other Publications

Computer Studies in the Humanities and Verbal Behavior
Floyd Horowitz, Editor
University of Kansas
Lawrence, Kansas

Subscription address:
Computer Studies in the Humanities and Verbal Behavior
Mouton
P. O. Box 1132
The Hague, The Netherlands $10.00 per year

d. Literature

1. Publication

Calculi
Stephen V. F. Waite, Editor
Department of Classics
Dartmouth College
Hanover, New Hampshire 03755

Bimonthly newsletter dealing with progress in the use of computers in classics, as well as bibliography and news notes about conventions and meetings. No charge for current issues.

e. Music

1. Publications

Allvin, Raynold, "Computer-Assisted Music Instruction: A Look at the Potential," A Laboratory Report, September 1968, Oakland University, School of Music, Rochester, Michigan 48063.

Ihrke, Walter, Final Report, "An Experimental Study of the Validity and Effectiveness of an Automated Rhythm Training Program," ERIC Document Reproduction Service, 4936 Fairmont Avenue, Bethesda, Maryland 20014, ED/0 32-7.

2. Mathematics and Physical Sciences

a. General

1. Organizations

American Association for the Advancement of Science
1515 Massachusetts Avenue, N. W.
Washington, D. C. 20005

Science, a weekly magazine which occasionally carries articles on computer use in education.

National Science Teachers Association
1201 16th Street, N. W.
Washington, D. C. 20036
Robert H. Carleton, Executive Secretary

Science Teacher Journal

"Computers--Theory and Uses", prepared by NSTA for secondary school classes, this unit has both a Student's Manual and a Teacher's Guide. The Manual gives basic information on computers, how they operate, and their place and uses in today's world. The guide includes source and reference materials. 1964. Individual titles $1.00.

b. Mathematics

1. Organizations

National Council of Teachers of Mathematics (NCTM)
1201 16th Street, N. W.
Washington, D. C. 20036

"Computer Assisted Instruction and the Teaching of Mathematics," Report of a national conference, 1969, 152 pp., $2.00.

"Computer Facilities for Mathematics Instruction," Information on educational uses of computers at the secondary school level, 1967, 47 pp., $.90.

"Computer Oriented Mathematics," Basic principles of automated computation as they relate to mathematics, illustrated, 1963, 204 pp., $2.50.

"Introduction to an Algorithmic Language (BASIC)," 1968, 49 pp., $1.40.

"Computer Applications for Mathematics Education - Selected Bibliography," January 1969, 7 pp., no charge.

Journal of Research in Mathematics Education, quarterly.

The Arithmetic Teacher
The Mathematics Teacher
Both are published 8 times a year with occasional articles on the use of computers in teaching and learning. The Mathematics Teacher contains a regular column on "Computer-oriented Mathematics."

Mathematics Association of America (MAA)
1255 Connecticut Avenue, N.W.
Washington D.C. 20036

Committee on the Undergraduate Program in Mathematics (CUPM)
Dr. Herbert Greenberg, Chairman

CUPM Newsletter
CUPM Central Office
P. O. Box 1024
Berkeley, California 94701
Editors: Gerald Leibowitz and George Pedrick

Committee on Educational Media
P. O. Box 2310
San Francisco, California 94126

Center for Research in College Instruction of Science and Mathematics (CRICISAM)
Dr. Guenter Schwarz, Director
212 Diffenbaugh
Florida State University
Tallahassee, Florida 32306

Computer-related course in calculus

ACM Special Interest Groups on:

Numerical Mathematics (SIGNUM) - Newsletter
Mathematical Programming (SIGMAP) - Newsletter
Symbolic and Algebraic Manipulation (SIGSAM) - Bulletin

c/o ACM National Headquarters
1133 Avenue of the Americas
New York, N. Y. 10036

2. Other Publications

Post, D., "The Use of Computers in Secondary School Mathematics," 1970, 251 pp., $4.95. Available from Entelek, 42 Pleasant Street, Newburyport, Massachusetts 01950

Computing Concepts in Mathematics (CCM)
Educational Planning
Science Research Associates, Inc.
259 East Erie Street
Chicago,Illinois 60611

This two semester course is designed to give secondary and college students insight into computing and the use of the computer as a tool in the study of mathematics.

CAMP (Computer Assisted Math Program)
David Johnson
University of Minnesota
Minneapolis, Minnesota.

c. Computer Science

1. Organizations

ACM Special Interest Groups on:

Computer Science Education (SIGCSE) - Bulletin
Computer Graphics (SIGGRAPH - Newsletter COMPUTER GRAPHICS
Real-Time Processing (SIGREAL) - Newsletter
Computer Personnel Resources (SIGCPR) - Newsletter
University Computing Centers (SIGUCC) - Newsletter

Association for Educational Data Systems (AEDS)
1210 Sixteenth Street, N. W.
Washington D.C. 20036

AEDS Monitor - monthly newsletter
Journal of AEDS - quarterly
Special attention to secondary school programs

d. Physics

1. Organizations

Commission on College Physics (CCP)
John M. Fowler, Director
(Department of Physics and Astronomy)
University of Maryland
4321 Hartwick Road
College Park, Maryland 20470

The Computer in Physics Instruction, proceedings of a Conference, November 4-6, 1965, at the University of California, Irvine. Previously available from Commission on College Physics; to be replaced by the proceedings of the 1970 conference.

Conference on "Computers in Undergraduate Science Education," held at the Illinois Institute of Technology, Chicago, August 17-21, 1970, sponsored by CCP and ITT. Preliminary proceedings were available at the conference and the final proceedings are expected early in 1971.

Alfred B. Bork, Arthur Luehrmann, and John W. Robson, (Ronald Blum, ed.), Introductory Computer-Based Mechanics: A One Week Sample Course, November 1968.

Ronald Blum (ed.), Computer Based Physics: An Anthology, September 1969

Ronald Blum and Alfred Bork, "The Computer in the Physics Curriculum, American Journal of Physics, July 1970.

Center for Research in College Instruction of Science and Mathematics (CRICISAM)
Guenter Schwarz, Director
212 Diffenbaugh
Florida State University
Tallahassee, Florida 32306

"Computers in Physics Instruction," Physics Today September 1969. It will be updated in a forthcoming Unesco publication entitled "New Trends in Physics Teaching."

American Institute of Physics
335 East 45th Street
New York, N. Y. 10017

American Journal of Physics - 12 issues per year - it contains a section for description of instructional uses of the computer, including provision for obtaining copy of programs in computer-readable form. (Further details are given in Volume II Appendix C on recommendations for professional societies and publications.)

e. Chemistry

1. Organization

American Chemical Society
Division of Chemical Education

Journal of Chemical Education
Chemical Education Publishing Company
20th and Northampton Streets
Easton, Pennsylvania 18042
Spring 1970 issue includes articles on computers in education

National Academy of Sciences - National Research Council
Division of Chemistry and Chemical Technology
2101 Constitution Avenue, N.W.
Washington, D.C.

Committee on Computers in Chemistry
Dr. Peter G. Lykos, Chairman
Illinois Institute of Technology
Chicago, Illinois 60616

2. Other Publications

Modern Teaching Aids for College Chemistry (Serial Publication 18)
Advisory Council on College Chemistry
Stanford University
Stanford, California 94305

f. Biology

1. Publication

Proceedings of the Eighth Annual Symposium on Biomathematics and Computer Science in the Life Sciences, Houston, Texas, March 23,24, 1970. There was one session devoted only to CAI in the Biomedical Sciences.

g. Geology

1. Organizations

American Geological Institute
Council on Education in the Geological Sciences
2201 M Street, N. W.
Washington, D. C. 20037

Osborne, R. H., "Undergraduate Instruction in Geomathematics," Journal of Geological Education, Vol. XVII, No. 4, October 1969. Short Review reprint available.

Fox, W. T., "Computer-oriented Laboratory Exercises for Geology and Oceanography," Journal of Geological Education, Vol. XVII No. 4, October 1969. Short Review reprint available.

American Association of Petroleum Geologists
Box 979
Tulsa, Oklahoma 94101

2. Other Publications

Kansas Computer Center Contribution Series Publications
Computer Center
University of Kansas
Lawrence, Kansas 66044

Published also in cooperation with the State Geological Survey

3. Behavioral and Social Sciences

a. General

1. Organizations

ACM Special Interest Committee on Computers and Society (SICCAS)
ACM Special Interest Group on Social and Behavioral Science Computing (SIGSOC)
c/o ACM National Headquarters
1133 Avenue of the Americas
New York, N. Y. 10036

SICCAS Newsletter - quarterly
SIGSOC Newsletter - quarterly

2. Other Publications

Green, Bert F., Digital Computers in Research, Holt, Rinehart and Winston, New York, 1963. Part III summarizes applications in behavioral sciences.

Stone, Philip J., The General Inquirer, M. I. T. Press, Cambridge, Massachusetts, 1966, 651 pp. Discussion of procedures for and applications of content analysis in psychology, sociology, political science, anthropology, history and literature.

Meyers, Edmund D. Jr., "IMPRESS and Undergraduate Education in the Social Sciences, " in Proceedings of a Conference on Computers in the Undergraduate Curricula, University of Iowa, Iowa City, 1970.

Meyers, Edmund D. Jr., "Interactive Systems and Social Science Research and Instruction," Social Science Information, June 1970.

b. Psychology

1. Organization

American Psychological Association
1200 Seventeenth Street, N. W.
Washington, D. C. 20036

American Psychologist, a monthly publication

The Journal of Educational Psychology, bi-monthly publication

Educational Psychologist, newsletter of Division 15 (Educational Psychology)

c. Sociology

1. Publication

Cline, Hugh F. and Edmund D. Meyers, Jr., "Problem Solving Computer Systems for Instruction in Sociology," in The American Sociologist (in press)

d. Political Science

1. Organization

The American Political Science Association
1527 New Hampshire Avenue, N. W.
Washington, D. C. 20036

Committees on Pre-Collegiate Education and Undergraduate Instruction

A Committee on Scientific Information Exchange may undertake activity in the area of instructional use of the computer.

e. Geography

1. Organization

Commission on College Geography
Dr. John Lounsbury, Director
Department of Geography
Arizona State University
Tempe, Arizona 85281

"Computer-Assisted Instruction in Geography," Technical Paper No. 2

Panel on Computer Assisted Instruction
Dr. Kennard W. Rumage, Chairman
Department of Geography
State University College at Brockport
Brockport, New York 14201

f. History

1. Organization

Mathematics in the Social Sciences
Subcommittee on Mathematics and Statistical Methods in History
Dr. Robert W. Fogel, Chairman
Department of Economics
University of Chicago
Chicago, Illinois 60637

2. Other Publications

Historical Methods Newsletter
Jonathan Levine, Editor
Department of History
University of Pittsburgh
Pittsburgh, Pennsylvania 15213

A quarterly newsletter publishing short articles, research notes, review essays and announcements. The editorial office maintains an active file of reports of research in progress and can respond to queries for information about particular techniques or data.

4. Professions

a. Architecture

1. Organizations

American Institute of Architects
Frank L. Codella, Administrator
Department of Professional Services
The Octagon
1735 New York Avenue, N. W.
Washington, D. C. 20006

A non-profit corporation sponsored by AIA is
Production Systems for Architects and Engineers, Inc.
343 South Dearborn Street
Chicago, Illinois 60604

ACM Special Interest Group in Urban Data Systems, Planning, Architecture and Civil Engineering (SIGSPAC)
c/o ACM National Headquarters
1133 Avenue of the Americas
New York, N. Y. 10036

SIGSPAC Bulletin - bi-monthly

b. Business

1. Organizations

Project on Computers in Management Education
Michael S. Scott Morton, Director
Alfred P. Sloan School of Management
Massachusetts Institute of Technology
50 Memorial Drive
Cambridge, Massachusetts 02139

ACM Curriculum Committee on Computer Education for Management
Professor Daniel Teichroew, Chairman
Department of Industrial Engineering
College of Engineering
University of Michigan
Ann Arbor, Michigan 48104

Report in preparation; May 1969 interim report available.

ACM Special Interest Group on Business Data Processing (SIGBDP)
c/o ACM National Headquarters
1133 Avenue of the Americas
New York, N. Y. 10036

Administrative Data Processing Group (IAG)
International Federation for Information Processing (IFIP)
6 Stadhouderskade
Amsterdam 13, The Netherlands

IAG Journal, quarterly

c. Education

1. Organizations

National Association of Secondary School Principals (NASSP)
Committee on Computers in Education
1201 Sixteenth Street, N. W.
Washington, D. C. 20036

Series of executive seminars for educational administrators on the computer in education

National Education Association
1201 Sixteenth Street, N. W.
Washington, D. C. 20036

NEA Handbook, published annually, available from the Publication-Sales Section at $2.00 a single copy.

American Educational Research Association (AERA)
1126 Sixteenth Street, N.W.
Washington, D.C. 20036

Special Interest Group on Computer Aids to Learning
Robert Seidel, Chairman
HumRRO Project IMPACT
300 N. Washington Street
Alexandria, Virginia

d. Engineering

1. Organizations

American Society of Engineering Education
Suite 400
One Dupont Circle
Washington, D. C. 20036

Committee on Computers in Engineering Education
Committee on Educational Research and Methods
Committee on Information Systems

Engineering Education, a monthly publication, September through June, $16.00.

National Academy of Engineering
Commission on Education
2101 Constitution Avenue, N. W.
Washington, D. C. 20037

Committee on Instructional Technology

"Educational Technology in Higher Education: The Promises and Limitations of ITV and CAI," Report of the Committee on Instructional Technology of the Commission of Education of the National Academy of Engineering, John R. Whinnery, Chairman, Washington, D. C., September 1969.

Committee on Computer Science in Electrical Engineering (COSINE)

e. Journalism

1. Organization

Association for Education in Journalism
Ralph O. Nafziger, Executive Secretary
425 Henry Hall
University of Wisconsin
Madison, Wisconsin 53706

Division on Theory and Methodology
Lionel C. Barrow Jr., Chairman
Research Department
Foote, Cone & Belding
300 Park Avenue
New York, N. Y. 10017

f. Law

1. Organization

The American Association of Law Schools
1521 New Hampshire Street, N. W.
Washington, D. C. 20036

Committee on Teaching Methods
Arthur R. Miller, Chairman
335 Hutchins Hall
University of Michigan
Ann Arbor, Michigan 48104

g. Library Science

1. Organization

American Library Association
Information Science and Automation Division
50 East Huron Street
Chicago, Illinois 60611

Committee on Library Education
Committee on Inter-Divisional Education

Journal of Library Automation - quarterly, professional journal containing information on original work in computer applications for data processing in libraries.

JOLA - Technical Communications - monthly newsletter

monograph - "Library Automation - A State of the Art"

h. Medicine and Dentistry

1. Organizations

Continuing Education and Training Branch
Division of Regional Medical Programs
National Institutes of Health
Department of Health, Education and Welfare
Bethesda, Maryland 20014

Various regional programs include projects on the instructional use of computers.

Lister Hill National Center for Biomedical Communications
8600 Rockville Pike
Bethesda, Maryland 20014

Davis, Ruth M., "Technology in Support of Medical Education," Lister Hill National Center, February 1969.

Clearinghouse for Programmed Materials in Medical Education and Health Care
University of Rochester School of Medicine and Dentistry
Rochester, New York 14620

ACM Special Interest Group on Biomedical Information Processing (SIGBIO)
G. Otto Barnett, Chairman
c/o ACM National Headquarters
1133 Avenue of the Americas
New York, N. Y. 10036

SIGBIO Newsletter - published every two months

Professional Education Branch
Division of Dental Health
National Institutes of Health
Department of Health, Education and Welfare
Bethesda, Maryland 20014

Proceedings of the conference "Instructional Technology in Dentistry," a report of the Conference on Computer Applications in Dental Education, held in San Francisco, October 29-31, 1969. Available from the Dental Health Center, 14th Avenue and Lake Street, San Francisco, California 94118.

2. Other Publications

Computer Programs in Biomedicine
North Holland Publishing Company
P. O. Box 3489
Amsterdam, The Netherlands (published quarterly)

International Journal of Biomedical Computing
J. Rose, Editor
Blackburn College of Technology and Design
Blackburn, England (published quarterly)

Proceedings of "Conference on the Use of Computers in Medical Education," April 3, 4, and 5, 1968, Oklahoma City, Oklahoma. Available from the University of Oklahoma Medical Center, 800 N. E. 13th Street, Oklahoma City, Oklahoma 73104.

Proceedings of an ONR-supported conference, "Computer Assisted Instruction in the Health Professions," held in Cambridge, Mass. in February 1968. Edited by Lawrence M. Stolurow, Theodore Peterson, Anne Cunningham, Entelek, Newburyport, Massachusetts.

i. **Social Work**

1. Organization

Council on Social Work Education
345 East 46th Street
New York, N. Y. 10017

A catalog of audio visual and other technological aids for teaching; one would expect information about computer uses to be included as it becomes available.

j. Urban Planning

1. Organization

ACM Special Interest Group on Urban Data Systems, Planning, Architecture and Civil Engineering
c/o ACM National Headquarters
1133 Avenue of the Americas
New York, N. Y. 10036

SIGSPAC Bulletin - bi-monthly

VOLUME I - APPENDIX B

INTERPRETIVE DESCRIPTION OF REPRESENTATIVE PROJECTS

Summaries of a number of projects are provided in this appendix to give a reader who is new to the field an indication of the diversity and depth of research and applications. Directors of a sample of projects were invited to present in two or three pages the overall goals, procedures and successes of current efforts. Some were unable to respond on the time schedule for preparation of this document, and staff of Project CLUE adapted an existing statement to serve the purpose.

The reader should gain an idea of what he would find if he were to look further into the technical reports and descriptive material for each project or to visit the site. Hopefully these brief statements will encourage the reader to obtain further information on projects which particularly interest him.

Only a few representative projects are included in this appendix, and each fits into more categories than the one for which it is listed. A list of all persons and projects contacted during the study is given in Appendix B of Volume II.

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Address comments to:

Karl L. Zinn, Director
Project CLUE
1315 Hill Street
Ann Arbor, Michigan 48104

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McComb Public Schools
McComb, Mississippi

The McComb Computer Assisted Instruction Project had as its initial goal to determine if computer-assisted instruction is feasible for use in a typical school setting. Documented evidence indicates that the system developed by Patrick Suppes for drill-and-practice in elementary mathematics is viable educationally. Our effort, however, was primarily intended to determine whether this program is practical.

Our school district is a rather typical Mississippi municipal separate school district, although above average in per-pupil expenditure. Our resources were rather modest in a number of areas: expenditure per pupil, staff, physical facilities, and resources to support the educational program. We saw in computer-assisted instruction an opportunity to upgrade considerably the instructional program of our school district if: we could afford it; our teachers could learn to use it effectively; administrative problems were of no real consequence; it did not create too many technical problems; and if it produced the desired educational gains in our student body.

After two and one-half years of using the Suppes' drill-and-practice program, we can say without equivocation that this program meets all of the criteria outlined above with the exception of cost. Quite frankly, we now believe that the cost factor is not an insurmountable hurdle. Drill-and-practice CAI systems do offer a relatively inexpensive opportunity to provide individualized drill for skill subjects. At the moment, excellent programs are available in mathematics and English. Admittedly, these programs are designed only as a supplement to classroom instruction; however, they do provide the potential for strengthening vital skill areas for elementary pupils by partial replacement of direct teacher supervision.

Our research data indicate that drill-and-practice CAI has particular relevance to current needs in providing instruction for the disadvantaged child. Our experience shows that gaps in achievement between populations of the disadvantaged and all other children can be narrowed by the use of computer-assisted instruction. Evidence may yet be developed to indicate that, from the standpoint of cost effectiveness, computer-assisted instruction should be provided only for those groups of pupils who profit substantially from the program. We believe that the brighter children, particularly those who are economically advantaged, do not profit sufficiently from computer-assisted instruction to merit the cost of this instructional program. Some challenge our belief in this matter, but we hold to our position until further research disproves our contention.

From technical and cost standpoints, a hardware system should be composed of small digital computers which provide daily drills to pupils on the simple terminal such as the Teletype ASR-33 terminal. The results of daily drill performance in this satellite system are easily "batch processed" on a larger computer and drills for subsequent days' lessons produced for return to the satellite system. In school systems which have available time on the data processing computer for administrative services, the small computers and terminals constitute the main hardware cost. Where possible, the teletype terminal should be hard-wired to the digital computer to avoid major communication costs.

Properly utilized, computer-assisted instruction can actually replace some classroom teacher time. The combination of computer-assisted instruction with an excellent classroom teacher is only slightly more expensive, over the long run, than straight classroom teacher instructional cost. Figures should be available soon to substantiate the contention that computer-assisted instruction which replaces a portion of the classroom teacher's time will be relatively inexpensive even when including the cost of computer hardware in total budgetary calculations.

Computer-assisted instruction utilizing drill-and-practice represents a very limited application of the wide range of instructional techniques which can be instituted using sophisticated computer hardware. However, this approach using small satellite computers to administer daily drills is a significant technique which can meet the test of practicality in an operating school program today.

Mr. Julian Prince
Superintendent of Schools
McComb Public Schools
McComb, Mississippi
January 10, 1970

Reference

Prince, J. B. "Computer Assisted Instruction in the Elementary School," AEDS Monitor, January 1969, pp. 1-3.

Division of Instructional Systems
The School District of Philadelphia

The School District of Philadelphia has been a pioneer in the use of computers in the instructional process. Recognizing the critical function the computer plays in education, the School District of Philadelphia is involved in the following areas:

1. Developing and implementing courses in computers so that students can apply them to various disciplines and be aware of their cultural significance.
2. Developing curricula designed to acquaint students with career opportunities in data processing and to help them develop the skills necessary to enter this vocational field.
3. Using computers to facilitate and individualize instructional processes.
4. Training teachers and other staff members of the School District in the use of computers so that they may apply them to the improvement of instruction.
5. Developing, implementing, and evaluating new and promising techniques of teaching such as those involved in "Gaming Simulation."
6. Exploring innovational aspects of educational technology and developing innovational techniques.

The programs described in this report represent the main thrust of the Division of Instructional Systems at this time. Other areas are still to be explored.

At the Senior High School level, a variety of courses, equipment, and programs serve the object of giving students experience with computer problem solving.

Through actual experience with equipment, students develop familiarity with computers and an understanding of what computers can do, how they work, how they are programmed, and how they are utilized in business, science, and industry. As pupils learn about career opportunities in the computer field, they develop an awareness of the effect of the computer revolution on technology and its cultural implications upon our society.

As they become proficient in computer languages, students learn to use computers to solve problems in subjects such as mathematics, chemistry, and physics. They learn about problems which cannot be solved without the aid of a computer and they study the mathematics needed in the formulation of computer oriented problems.

The computer concepts course for junior high school students was introduced as a pilot project in five schools in September 1967. The success of that project has led to the expansion of the program so that by February 1970 every junior high school offered a course in computers to its students.

Junior high school students work at a teletypewriter terminal connected by telephone to a large computer. Students utilize the terminal to execute programs which they have written as part of the computer concepts course. The course is offered as a two-period minor to students in the ninth grade.

Over 2000 elementary school students have been helped to understand that a computer is not as mysterious as they might have thought. An exciting approach to learning is computerized games. Fifth grade students are participating in a program which utilizes a special audio-visual computer terminal to present the Sumerian game -- an economics-based simulation which places the student in the role of ruler of the ancient kingdom of Sumer. The participant evaluates reports from his council regarding the status of his kingdom and based on this makes decisions which affect the economy and well being of his people. The computer evaluates the student's decisions and adjusts its figures on the economic status of the kingdom accordingly.

Curriculum Development

Computerized games provide opportunities for decision making and approaches not easily experienced in the classroom. Games can promote discovery by simulating events, decision strategies and problems.

Since November 1967, students have been receiving individual instruction in reading and biology through a computer. A Title I grant to the School District of Philadelphia initiated the development of a large scale computer-assisted instruction program. The system consists of a central computer and five clusters of computers with eight terminals in each of five schools. The clusters are connected to the central computer, located at the Computer Center, by telephone lines.

The curriculum has been developed by School District of Philadelphia personnel. A 10th grade biology course includes instruction in biology, its history, science vs. superstition, scientific method, cell and cell theory, characteristics of life, and heredity. In reading the emphasis is on raising the reading level. Topics such as recognizing main ideas, following directions, and drawing conclusions are included. As a student encounters difficulty, he is branched to other, perhaps easier, presentation of material. A student who needs enrichment material is branched to this material. The student is directed into channels of instruction suited to his needs.

The School District of Philadelphia, in cooperation with the Regional Laboratory, Research for Better Schools, is developing individually prescribed elementary mathematics material consisting of placement tests, pre-tests, post-tests, and instructional material for computer assisted instruction. The materials are developed according to a list of carefully sequenced instructional objectives defined behaviorally. The objectives follow a continuum through the areas of basic mathematics such as place value, division, geometry, etc.

The CAI program is providing for continuous monitoring of the student's performance in terms of subject matter competence, differential mastery, and requirements for new learning. The burden of scoring and progress analysis is carried by the computer. Branching of the student according to his individual needs is automatic.

The computer and the automated processes associated with it have created dramatic changes in the employment situation. The Philadelphia School district was one of the first to recognize this and as early as 1961 had instituted courses in data processing. Since that time the program has expanded throughout the entire school system.

Facilities

The Instructional Computer Center serves as a focal point for many programs and activities. A large Philco 102 Computer housed here is the "driver" for smaller systems located in four secondary schools which provide Computer Assisted Instruction material for courses in biology and reading as part of their regular roster. In addition to servicing this purpose, the central computer provides computerized curriculum for the terminals in the computer center. Curriculum material for this system is prepared by teams of writers, programmers, coders, and technical staff housed at the Center.

The Center also services as a demonstration and evaluation location for automated education equipment. Manufacturers are encouraged to leave their equipment where it is evaluated by the staff and teachers and administrators.

The Center serves as the central agency in a time-sharing arrangement which provides computer time to all senior high schools and most of the junior high schools. Students in the schools communicate with an IBM 1130 computer at the center via a teletypewriter. Utilizing this arrangement, students have for their use in solving mathematics and science programs a computer which would be too expensive to supply to each of the schools. The School District of Philadelphia is the first school district to operate its own time-sharing system.

The Center serves the school district and the community by providing facilities for after school programs, staff development, adult education programs, etc. Home and school associations, community groups, neighborhood clubs, etc., are invited to attend lectures and courses explaining how computers work.

At present, studies are being made to make CAI more universally available at greatly reduced costs. Plans are underway to develop new computer-based games; procedures which would involve many more teachers and students are under development.

Prepared by the Project CLUE staff from "Computers in the Instructional Program," from the 1968-69 Annual Report of the Division of Instructional Systems, Dr. Sylvia Charp, Director

Reference

Charp, Sylvia and John Woolson, "Using a Computer to Teach," AEDS Monitor, vol. 7, January 1969, pp. 6-7.

Project LOCAL
44 School Street
Westwood, Massachusetts 02090

Project LOCAL, the Laboratory Program for Computer-Assisted Learning is a five-town cooperative endeavor set up to improve instruction by using the computer as a teaching aid. LOCAL, which for three years was a Title III ESEA project, is now chartered in Massachusetts as a tax-exempt educational corporation. Its membership includes the towns of Lexington, Natick, Needham, Wellesley, and Westwood.

LOCAL's five PDP-8 computers, which can accomodate over 3,500 students, provides services to over fifteen school systems in the Boston Metropolitan area. LOCAL has trained over 200 teachers from this area in the techniques of teaching via computerized problem-solving.

The over-all goals of LOCAL are as follows:

1. To improve the achievement of mathematics and science curriculum objectives, especially in the areas of achievement, problem-solving skills, and attitude.
2. To teach to the widest possible segment of the pupil population a basic understanding of the computer in its role as an important element of modern society.

In order to achieve its objectives, LOCAL conducts the following programs:

1. Using the computer as a teaching aid in the regular math and science curricula to accomplish ends such as motivation, reinforcing concept understanding (problem-solving and drill) concept demonstration, creation of discovery learning situations (simulation of systems to be studied), and increasing efficiency (automation of required operations).

2. Integrating instruction about the social implications of the computer into the regular social studies curriculum.

3. Organizing and sponsoring computer clubs to provide an outlet for students with special interests and to teach computer concepts not normally taught in a math or science class.

4. Setting up and maintaining a participating membership program to provide computer services to other school systems.

5. Conducting pilot programs with appropriate experimental structuring in order to further evaluate the usefulness of the computer as a teaching aid.

The Project LOCAL staff, consisting of three full-time persons and several part-time consultants, carries out a number of activities required to support the programs outlined above. These activities include installing and maintaining a library of materials concerning instructional uses of computers, disseminating information via a project newsletter, in-service training of the instructional staff, writing instruction-related computer software, writing applications for outside funds, and central purchasing of supplies for teletypewriters.

Project LOCAL uses several different activities to realize its goal of improved instruction. However, by far the most commonly used one is the simple device of having students solve problems on the computer. This method, much like many traditional ones, has students solve exemplary problems following the explanation of new principles or ones being reviewed. However, this method is somewhat unique in that it shifts emphasis from results (answers) to the procedure used for problem-solving.

A student comes to understand a principle much better in the process of explaining how to use that principle in problem-solving. The algorithmic method employs the computer as the party to whom the student explains the steps (program) required for problem solution. In this way, the student gains all the benefits of having "taught" someone how to use the principle being studied and also obtains rapid feedback concerning the accuracy of his "teaching" i.e., his program either runs or does not. Where a program does not run, the student accomplishes any necessary relearning by finding and correcting his mistake(s).

The beneficial effect of having students solve problems on the computer is very aptly stated by this quotation from signs that hang on the walls of math classes in Altoona, Pa., "If you want to learn a subject - teach it. If you really want to learn a subject - program it for a computer."

The primary benefits of computerized problem-solving are improved concept understanding, enhanced problem-solving skill, and motivation. In addition, it also imparts benefits such as: allowing for individual approaches to problem-solving; enabling teachers to quickly locate weaknesses in student comprehension; allowing teachers to assign general-case rather than exemplary problems; and preparing students for later work in either a job or at the next level of education.

During the 1969-1970 school year, approximately 1,300 students in LOCAL's five member school systems were involved in learning enriched through the use of the computer as a problem-solving vehicle. The two programming languages used were FOCAL, developed by Digital Equipment Corporation, and BASIC.

LOCAL has published several funding applications, an evaluation report and several documents useful to the classroom teacher. The latter include:

Computers in the Classroom by Walter Koetke - Resource manual for algebra teachers; includes teaching strategies and computer programs (130 pp.)

Resource Materials for Computer-Assisted Science Teaching Manual for science (primarily chemistry) teachers; includes teaching strategies and computer programs (226 pp.)

Future Plans

LOCAL has applied for outside funding to design, to produce, and to evaluate a computerized clerical support system for individualized instruction which would be more capable than manual systems and far more economical than previous computerized systems. This system would be fully exportable to other schools, yet the presence of computer equipment and trained computer educators already in our schools would reduce development costs considerably below what they would be otherwise.

Wherever truly individualized instruction is to be implemented on a wide-scale basis, there is a pressing need for a means of collecting, processing, and presenting the data needed by teachers to perform functions such as: diagnosing learning needs, prescribing learning experiences, accounting for learning materials, keeping track of student progress, analyzing the effectiveness of test items, etc. To date, the most successful agents for solving this problem have been: (1) teacher aides and (2) medium-and large-scale computer systems. Both of these solutions are relatively expensive alternatives.

Three of our school systems are in the process of implementing wide-scale, truly individualized programs, and they have an urgent need for an economical means of clerical support for these programs. The other two cooperating school systems are taking steps to implement less ambitious programs; their needs in this area, although less immediate, will become apparent in a few years.

Preliminary investigation finds no obstacle preventing the use of Project LOCAL's small computers, which are already serving the classroom well, in the additional capacity of clerks to grade tests, to keep records, and to write reports in support of individualized instruction. If such machines are found to do the job adequately, the over-all cost of computer-aided instruction will have been reduced substantially and the teacher will have available an extremely well-rounded tool: one that helps in teaching and also helps with the attendant bookkeeping.

Robert N. Haven
Project Director

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Thank you.

Center for Research on Learning and Teaching
University of Michigan, Ann Arbor

The research and development program at the Center for Research on Learning and Teaching (CRLT) provides a focus for many University activities concerning the utilization of on-line computers in teaching. Instructional technology has been a major concern of the Center since it was established by the Regents of the University in 1962 in response to recommendations from several faculty committees. Exploration of computer utilization is coordinated with other Center programs concerned with programmed instruction, instructional technology, academic games, instructional television, preparation of college teachers, and the personal and social development of students.

Facilities

Computer-based instruction facilities in use at CRLT have been acquired and developed in response to the expressed needs of potential users. Faculty members and students identify situations which might benefit from the use of computers or other technology, and describe self-instruction procedures which should help solve problems. Technical assistants experienced with various computer systems and techniques help implement appropriate teaching and learning applications suited to the professor's goals and procedures as well as to the individual needs and interests of students.

Since early 1968 most instructional applications have been operated from the IBM 360/67 on campus. The Michigan Terminal System (MTS) provides a powerful capability for design of instructional applications in a number of areas. The major direction of computer facility development on campus has been to make use of one large general-purpose time-sharing system for instructional as well as scientific computing. As a result use of the computer for instruction of students has been closely associated with use of the computer for research. This situation has avoided the somewhat artificial separation of instruction and research which may follow from the allocation of small and separate computers to instructional tasks within a university.

Some research on instructional use of computers does use separate facilities. Using a PDP-9 with a TV display, William R. Uttal at the Mental Health Research Institute (MHRI) is developing a generative computer-assisted instruction system for tutoring students in analytical geometry and other mathematical topics. The Center for Research on Language and Language Behavior developed a Speech Audio Instruction System(SAID) for research on training of prosodic characteristics of speech around a single terminal based on a PDP-4. James Greeno of the Human Performance Center is assembling a laboratory for research on parameters of individualized instruction, using a small IBM 1800 and CRT display devices.

MTS offers the user a wide variety of languages and powerful command and file capability. The variety of computer languages available enables an author to select the language best suited to each part of his instructional task. Often he finds it desirable to obtain the aid of one versed in computer applications to program the material in the most efficient manner for the problem at hand. Recently, computing techniques and packages have been developed for incorporating new learning tasks into curricula in the humanities and social sciences as well as engineering and science.

The most common user-terminal devices on campus are the Teletype models 33 and 35. Several IBM 2741 or Datel selectric typewriter devices offer quieter operation and a more complete set of characters. In addition, applications of graphics display devices in instruction are being developed in a number of discipline areas.

Demonstrations and Seminars for Faculty

Faculty are invited to try selected examples of computer-based learning exercises as "students" at a learning station and to study the documentation provided by the author that indicates the information stored in the computer. However, it is difficult for an individual to get an accurate impression of the potential and limitations of a computer instruction system through material in an unfamiliar field. A sufficiently advanced sequence of instruction in a particular field probably requires that the "student" have a general background and specific preparation in that field.

Therefore, interested faculty members are encouraged to write their own specifications for possible programming of an instructional exercise; Center staff implement those self-demonstrations. A brief experience as an author provides an interesting demonstration for a potential author, sample materials which might encourage a larger development project, and a critical test of the usefulness of the system. No previous experience with computers is necessary for success in "self-demonstration" of computer use for instruction.

Often faculty members are interested in transforming some aspect of their research use of the computer into a form suitable for instruction. For example, a professor who used the computer to simulate genetic phenomena in botany prepared exercises which enabled his students to interact with selected aspects of the same simulation model employed in his research. Through this approach, students were given access to and practice with some of the research tools which the professor used in his own work.

Since 1965 seminars and related author experiences have been offered to all departments and schools. During the past four years faculty from history and classics as well as the science and professional fields have participated.

Seminars are small (six to eight participants) and are staffed by two or three persons who have experience with computer instruction facilities now available to U-M faculty. In group meetings emphasis is placed on critical review of proposed learning exercises and the generation of new ideas. During individual work and consultation sessions each individual tests his ideas on a computer.

Author Experience

The development of instructional materials for computer-based systems is being pursued in many areas of liberal arts and professional curriculum, among them: physics, engineering, architecture, education, natural resources, public health, history, library science, economics, biology, and psychology. Languages designed for authors (e.g., COURSEWRITER, PLANIT, and FOIL) are easy to learn and use for tutorial instruction, but, correspondingly, the sequences prepared are often simple in strategy. An author wishing to implement interesting teaching strategies and sensitive recognition of student responses must add special functions to the "author" language. The programming thereby becomes complex; authors are advised to write specifications for an instruction sequence in any convenient but unambiguous way, and they must rely upon a technical assistant to translate the instruction into some "author" language or a more flexible translator.

A notation is evolving through which authors can give written instructions to a technical assistant who codes the material in one of the available languages. CRLT provides such assistance to U-M faculty or alternatively trains writing assistants already experienced in the subject area. One long-range goal of the CRLT program is the development of a flexible translator, or a system for writing translators, which will adapt a computer language and related support to individual authors and subject areas, thereby reducing the need to work through technical assistants.

As soon as an author has successfully executed a short learning exercise on the computer, he is encouraged to have a student try the material and strategy. The author can revise his first draft on the basis of the student's performance and then have another student try the improved version. Typically, a cycle of test and revise is repeated with students a number of times before the author is satisfied that the exercise is ready to be put to use by students regularly enrolled for instruction.

A Strategy for Development

Collaboration of a professor with CRLT on instructional projects follows a typical pattern. The initial specification of goals and the development of a short instructional sequence or exercise are supported by CRLT funds and staff efforts. If the faculty member chooses to continue developmental work with computers in instruction he is encouraged to request technical assistance, computer time, and materials from the Wolverine Fund, a source of support for innovative instructional activities within the University.

Wolverine Fund support usually carries the project until the materials are in a form suitable for use within a class. Operational use of the computer for regular instruction is supported by the academic department with University resources. Often the professor obtains outside funding to expand research and development efforts for 1) a wider utilization of the computer within his discipline or 2) a revision of the curriculum incorporating computers.

At the conclusion of a sponsored research project the department again provides support for those operations which are justified for student use as an integral part of the curriculum.

Computer Networks for Instruction

For more than five years the Center has been involved in long range planning of inter-institutional applications of computers in instruction. A network involving the three largest universities in the State (Michigan State University, Wayne State University and the University of Michigan) has been developed through the Michigan Interuniversity Committee on Information Systems (MICIS). The cooperative endeavor of the three institutions to develop and implement a prototype for instructional computer usage in the state is strengthened by the incorporated Michigan Education Research and Information Triad (MERIT). Ultimately, most universities, colleges, schools and perhaps some state agencies will share certain facilities for instruction that would not otherwise be available to them.

Karl L. Zinn
Research Scientist
Center for Research on Learning and Teaching
Ann Arbor, Michigan
May 15, 1970

Reference

Zinn, Karl L. "Programming Conversational Use of Computers for Instruction," pp. 85-98 in Proceedings of the 1968 ACM National Conference. Princeton: Brandon Systems Press, 1968. Reprinted in R. C. Atkinson and H. A. Wilson. Computer-Assisted Instruction: A Book of Readings. New York: Academic Press, 1970, pp. 253-68.

Kiewit Computation Center
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Convinced that all liberally educated students must be exposed to computation and know how to deal with it, Dartmouth College in 1964 constructed a time-sharing system open to all students and faculty. Recognizing that the vast majority of students could not be reached through conventional, card-oriented batch systems, time-sharing with terminals in places convenient to students was deemed necessary. In addition, a very simple user interface was provided and a new language, BASIC, developed.

The main emphasis of the Kiewit Center has been to provide high quality and easy-to-use service to as many students and teachers as possible on both the college and secondary school levels. By mid-1970, about 200 terminals, mostly teletypes, were in place in 35 secondary schools and 15 colleges besides Dartmouth. Most of these are active during peak periods -- about 135 can operate simultaneously -- and a typical day during the school year will see a total of 1000 terminal hours recorded and about 10,000 "jobs" run.

While the main purpose was to provide service to the whole community, it was early recognized that organized efforts at curricular materials development was necessary if the use of the computer were to progress beyond the obvious first examples. Therefore, each major project at the Kiewit Center included a materials development aspect. The principal projects are summarized below, together with a brief description of the materials produced.

1. Original Development Project (to develop the time-sharing system and the BASIC language) Produced a manual for BASIC, and five teaching supplements for number theory, statistics (2), logic and linear algebra.

2. Secondary School Project Produced about 35 "topic outlines" about eight of which were published for regular distribution and use by students and/or teachers. In addition, the project produced one book, Elementary Functions, and one longish introductory text, School Basic. A proposed continuation of the project will produce about six more short curricular units.

3. College Consortium Project. The main purpose was to provide service and record the nature of use in the participating schools. No materials as such were produced.

Recognizing that the broad spectrum of uses in the curricula experienced in the Dartmouth network fell far beyond the traditional understandings of CAI, a new Center has been established at Dartmouth. The Computer Educational Materials Development Center will encourage a wide variety of curricular uses and materials development, and will provide the crucial summer support and technical editing assistance necessary to bring the materials to usable levels of quality.

Professor Arthur W. Luehrmann
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The Illinois Institute of Technology has long recognized that the computer represents an emerging new discipline which impinges on other academic areas. The University's computer operations are therefore set up within an interdisciplinary Computation Center which is divided into an Information Processing Center and an Information Science Center. The Information Processing Center, a service facility, operates and maintains computer equipment and provides advice, counseling, analysis, and programming support to computer users. The Information Science Center, an established part of the IIT academic program, carries out research and teaching in the field of high-speed computers.

Through its Information Science Center, IIT offers graduate instruction leading to the degrees of Master of Science, and Master of Science for Teachers in Information Science. The Information Processing Center's computer facilities are used by other academic disciplines for graduate research. Undergraduate students interested in the field are encouraged to develop strong minors or co-majors in Information Science. All undergraduates at IIT are required to take at least one introductory computer course. More than half of all undergraduates use the center's computer to support their course work during any given year. In addition, the center teaches and works not only with the university students but teachers as well, underscoring the fact that education for the modern man or woman, including the teacher, is a lifelong process.

However, IIT's efforts to find ways of effectively bringing computers to the classroom are not restricted to the university itself or to universities in general. IIT has, in fact, given special and continuing attention to the need for systematic development of computer-related courses of study below the university level. This has involved pioneering in the adaptation of high-speed computer systems to support large numbers of educational users with small problems and programs.

The layman tends to regard the computer as too complicated and too expensive for use by masses of non-university students. But programs operated by IIT have demonstrated that neither the aptitude of students (or their teachers!) nor the cost of processing programs need necessarily be barriers to the use of computers in secondary and even elementary schools.

Since 1961, for example, the university has conducted a Saturday Secondary School Computer Science Education Program. This program has brought 14,000 students and 1,200 teachers from more than 400 high schools in the Chicago metropolitan area to the university to learn how to program a computer.

Initial participation in this program by two Chicago public high schools led to acquisition by the Chicago Board of Education of a copy of an early IIT computer system to support all 60 of its high schools. This was further enhanced by the fact that 200 Chicago high school teachers participated in the IIT Saturday programs.

Highly motivated, average, as well as above average, students have shown themselves fully capable of learning computer programming. Through a series of Saturday academic programs, at the University, 10 per cent of the secondary students taking the introductory course have continued with advanced instruction in computer applications.

Both students and teachers pay a fee to attend the Saturday program, but the charge is nominal, primarily due to the fact that IIT is able to provide significant computer experience at a program processing cost which is significantly less than that of circulating a book from a public library. The cost of circulating a library book is estimated at 60 cents. The cost for computer-processing a student or teacher problem at IIT is less than 25 cents.

This low-cost processing is a result of several factors. The IIT Computation Center, for example, has engaged in extensive development of application programs designed for maximum accomodation of computer capabilities to the educational environment. The Center has also developed a Remote Job Entry System which makes it possible for a wide variety of peripheral equipment - card readers in the Center's data preparation area or teletypewriters in a separate laboratory - to communicate directly with a computer. This system uses economical batch processing methods under the control of an automatic scheduler while providing users with complete access to the full range of application programs stored in the computer's library, including many developed by the users of the IIT network.

In addition to software development providing remote terminal access at very low cost, IIT has developed a comprehensive third generation language and supporting compiler. Called IITRAN, this modern language, which is designed to support classroom instruction, provides extremely comprehensive diagnostics which enable students to master programming in the shortest possible time.

Through the use of a viable subset of IITRAN, high school and college students are able to learn programming and begin using a computer productively after only one hour of instruction. The cost of computer time for an average student job is also reduced to a minimum. At the same time, experience with the language provides students with a firm basis for learning more restrictive, commercially used programming languages. This is because one of IITRAN's design objectives is to teach students basic programming concepts without the arbitrary restrictions of languages like FORTRAN.

IITRAN has also been translated into foreign languages. Formerly, non-English speaking students studying in the United States had to learn both the English language and a programming language to use a computer. Now, through the use of SPANTRAN, GAULTRAN, and DEUTRAN, Spanish, French, and German speaking students can become familiar with the computer in their native languages. What's more, the comprehensive and explicit error messages built into each of these equivalent foreign language compilers essentially convert the computer into a teaching machine for instructing foreign-born students in the use of the corresponding programming language.

Based on these programming and processing capabilities, IIT began a new computer educational program called Operation Compu-Tel in October 1966. This program uses all of the know-how developed by the IIT computation Center to bring the computer into remote classrooms via telephone lines. A teletypewriter installed at each participating educational institution is used to transmit problems directly to the Computation Center's computer and type out results fed back from the computer.

In July 1968 the National Science Foundation (NSF) awarded a grant to IIT and nine other participating colleges and universities in northern Illinois and southern Wisconsin to develop a regional computer network. The IIT-centered Project is the largest of 15 regional computer networks spanning the United States and partially funded by NSF. Each regional center emphasizes different aspects of computer-based educational activity. At IIT, computer hardware-software and programming training are de-emphasized since these are areas in which the university has already obtained considerable experience. Instead, IIT's 26-month project seeks to impact education at the undergraduate level through a planned cooperative curriculum development program.

Seventy-two faculty members from a current total of 15 participating institutions are grouped by seven academic disciplines to do curriculum development work under the guidance of seven group leaders. The seven academic disciplines are biology, business-management-economics, chemistry, mathematics, physics, psychology-education, and sociology.

The group leaders visit participating colleges at least once a term to assist in planning the use of computers within each individual college's curriculum. The leaders are also encouraged and funded to attend relevant conferences and to visit other leading institutions around the country to learn more about how their academic disciplines are being enriched through the use of computers.

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North Carolina Educational Computing Service
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The North Carolina Educational Computing Service (NCECS) was created by the State Board of Higher Education in July 1969 to provide computing service to educational institutions throughout the State. NCECS is the successor to the North Carolina Computer Orientation Project (NCCOP), a grant-supported program which began in 1966 and terminated officially in October 1969. Utilizing the facilities of the Triangle Universities Computation Center (TUCC)*, NCCOP brought remote computing to the campuses of forty-three institutions of higher learning and established one of the first intercollegiate computer networks in the United States. Most of the institutions which took advantage of the NCCOP offer of free service elected to continue the computer terminal at their expense when the orientation period terminated, creating a continuing need for a central organization.

The Computer Orientation Project was an experiment. The objective was to see how many of the 90 eligible institutions would participate and how many, when they got to the end of their one-year free trial, would be willing to put their own money into computing activities. A few already had on-campus computers. Thirty-two of the 43 institutions retained the terminal after the free period expired, assuming all associated costs, and most of these have continued remote computing without interruption. Moreover, the project through its regional meetings, workshops, and publications, had a broader effect on higher education in North Carolina in that it created and strengthened interest in academic computing at many of those colleges which never accepted the offer of free service. Some of these have since joined the network, and faculty members from others are participating in a cooperative program of curriculum development.

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*TUCC is a non-profit corporation jointly owned by the University of North Carolina at Chapel Hill, North Carolina State University, and Duke University and is equipped with an IBM System/360 Model 75 computer.

NCECS is a service rather than an experiment. Past experience proved that the small user--in particular, the low-speed terminal user--requires special technical support, and needs to be represented by TUCC by someone who is primarily concerned with his needs. NCECS serves as the representative of all educational users other than the owners of TUCC. It provides these institutions with a low-cost computing service (including terminals, communications and computer time) and the necessary technical support (including information services, technical assistance to users and specialized software and documentation). The central staff currently consists of nine full-time and two part-time employees. The network now includes forty-two public and private institutions--universities, junior and senior colleges, community colleges and one high school system*.

In November 1969 the Board of Higher education received a two-year grant of $344,000 from the National Science Foundation for support of NCECS. This grant made possible an expansion of the central staff, together with a variety of new activities in the area of curriculum development. Twelve colleges in the network also received NSF grants (totaling $131,000) for the support of on-campus facilities. During the past year, these and other participating institutions have been able to acquire more powerful terminals, and users have been exposed to new facilities and provided opportunities for more sophisticated usage. Thus their needs for technical support and specialized documentation, rather than diminishing, have continued and expanded. There has been, however, a shift in emphasis from basic programming instruction to advanced training in the use of newly available, more sophisticated facilities and in applications of computer use in non-computing curricula.

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*Terminal equipment includes 16 Teletypes, 25 IBM 1050's, 8 IBM 2780's, and one IBM 1130. Three IBM 2770's are scheduled for installation in October 1970.

Curriculum development has been initiated by NCCOP with the formation of eight discipline groups and the organization of several workshops to bring these groups together. Dr. Joseph R. Denk, chemistry group leader for NCCOP, was added to the NCECS staff to supervise curriculum development activities funded by the NSF grant.

The curriculum development program is concentrating on five main areas: group activities, teaching unit (CEG) production, the publication of a program and literature service journal (PALS), workshops, and a consulting service. Group activity is coordinated by group leaders from participating colleges. Six discipline group leaders were funded during 1969-70 in business-economics, chemistry, engineering, mathematics, physics, and statistics. Four additional groups--biology, data processing, humanities, and sociology--were coordinated by the central staff. To date, curriculum development has made its greatest inroads in chemistry, engineering, sociology, and statistics.

NCECS has produced 11 Computer-based Educational Guides (CEG's), with 20 more in development. These discipline-oriented teaching units describe the usage of a particular "canned" program, and contain educational material as well as the usual type of computer program documentation. They are tested in workshop activity before publication. Support will be provided during the 1970-71 academic year for the development of teaching units by group members, as well as by the various leaders. The Program and Literature Service (PALS) is a journal used to communicate the existence of programs and literature concerning programs in use both inside and outside the NCECS network. Short abstracts of teaching units, programs, and journal articles are published quarterly for each discipline group. Group members are expected to contribute to PALS.

Workshop activity ranges from discipline group meetings to interdisciplinary sessions in areas of numerical methods, simulation, statistics (for everyone), and gaming. Visiting scientists are a regular part of curriculum workshops, and a consulting service is made available in all disciplines. Workshop activity is described in a recent report on "Spring Workshops in Curriculum Development", and general activity is reported in the bimonthly NCECS Newsletter.

At the end of the two-year grant period, many of the grant-supported curriculum development activities will terminate. By that time, the responsibility for continuation of this effort will have been shifted into the hands of the colleges. However, it is expected that the central staff will continue to provide coordination of some curriculum development activity in addition to its technical support functions.

Louis T. Parker, Jr., Director
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Research Triangle Park, North Carolina

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Parker, Louis T., Jr., et al. "Introducing Computing to Smaller Colleges and Universities--A Progress Report". Communications of the ACM 12:6, pp. 319-323, June 1969.

Denk, Joseph R. "Curriculum Development of Computer Usage in North Carolina", pp. 11.9ff in Proceedings of a Conference on Computers in the Undergraduate Curricula, University of Iowa, June 1970.

Faculty and Administrators Training Institute
Florida State University (FSU)

The Faculty and Administrators Training Institute was held from September 16, 1968 through June 15, 1969 for twenty participants. The overall objective of the Institute was to provide an opportunity for present and prospective college and university level administrators and faculty members to acquire an in-depth understanding of all aspects of computer-based multi-media instruction in college level education.

The program was guided by six general objectives which had been formulated from the previous Institute in 1967: 1) to acquaint the participants with the field of computer-assisted instruction; 2) to provide the participants with an understanding of the educational and learning theories that form the basis for the application of computers within instruction; 3) to develop a high degree of proficiency on the part of the participants in the utilization of the FSU Computer-Assisted Instruction system; 4) to develop knowledge about the newer techniques of data analysis such as sequential analysis, tests for instructional models, and dynamic decision-making; 5) to learn how to administer CAI installations so that the participant would understand the operational factors of cost, time schedule, course development and personnel; 6) to author a CAI course unit on the FSU CAI system and to evaluate its efficiency.

All of the participants achieved the Institute's objectives with varying degrees of success according to their particular academic orientation as well as their personal goals. In general, the overall goals of the Institute were accomplished in that all the students who participated received graduate credit and made excellent grades in their formal course work. During the three quarters of the Institute, the participants accumulated 45 quarter hours of graduate course work. The required courses for the trainees were as follows: Techniques of

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Programmed Instruction, Origins of Individual Differences Important in Education, Human Factors in Training and Instructional Systems, Computer-Assisted Instruction, Computer Analysis of Educational Data, Computer Simulation and Information Processes of Learning and Instruction, Quantitative Models of Instruction. Even more important than their success in course work, each participant made a significant contribution to the research and development of this new professional field via the authorship of learning materials and the successful solution of current developmental tasks.

The students believed that the use of the "Systems Approach" and the implementation of a learning sequence on the CAI system were the most significant activities of the Institute.

Moreover, a survey of Institute graduates from 1967-68,who are now serving in administrative and teaching positions primarily in junior colleges, revealed that 83 per cent considered their traineeship experience very worthwhile and 67 per cent indicated that skills learned in the traineeship are quite valuable in their current position.

It is important to note that 50% of the graduates believed that the traineeship had provided them with the opportunity to gain a more influential position in education than they might otherwise have obtained. This statistic, in conjunction with the trainees' perceived effectiveness of the training program, is critical both in terms of evaluating the immediate effects of the Institute and in estimating the potential long-term effects in the field of education.

The entire program was essentially strong. Only in the areas of prerequisite statistical skills and computer languages does there appear a need for future revision in terms of the nature and goals of the Institute.

The weekly seminars were considered a problem by the trainees in that they demanded considerable time and preparation on a broad range of topics. Additionally, the challenge of complex quantitative analyses and model building left the better students with a desire to investigate these topics in greater depth than was provided by the program. In the economic sphere, the participants consumed considerably more CAI computer time than covered by the budget; these costs were absorbed by Florida State University.

In general, the objectives of the Institute can be recommended for professional development in the area of computers and education. The nine month length of the program allowed a thorough introduction and orientation to the nature and potential of computer assisted learning. A full academic year appears to be the absolute minimum time needed to develop competency in CAI. Communication between faculty and students was extensive and profitable. The greater emphasis on practical experience at an earlier time proved to be of great help to the participants in that they could formulate their individual projects earlier, allowing more time for project evaluation, analyses, and completion.

Adapted by Project CLUE staff from the Final Report of the Institute in Computer-Related Multi-Media Instruction for Administrators and Faculty in Junior Colleges and Universities prepared by Duncan N. Hansen, Walter Dick and Henry T. Lippert, July 1969

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Hansen, Duncan. "Development Processes in CAI: Problems, Techniques and Implications," pp. 36-47 in Proceeding of a Seminar on Computer Based Learning Systems, September 8-12, 1969. National Council for Educational Technology: London, March 1970.

Field Engineering Education
IBM Education Center
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The IBM Field Engineering Division consists of highly skilled Customer Engineers who provide service and maintenance for IBM's wide range of products. These Customer Engineers are located in major cities throughout the United States. A high rate of technological change represented by a continuous stream of new products presents a tremendous challenge in providing adequate up-to-date training for these Customer Engineers. The magnitude and demanding nature of this educational requirement quite naturally led to the exploration of Computer Assisted Instruction (CAI).

Before the advent of CAI, the training consisted primarily of two major areas: t[illegible]nd-up lecture portion and the laboratory portion which gives the students a chance to work on real equipment. The time distribution between these two portions of training is approximately 50/50. In other words, 50% of the student's time is involved in lecture-type learning experiences and 50% of his time is involved in laboratory learning experiences.

In early research with CAI in Field Engineering Education, the lecture materials (referred to as theory training) were prepared for presentation via CAI. However, the approach taken required that the CAI materials be provided the student before he received any hands-on training in the laboratory. In courses as lengthy as 25 days, 12 or 13 days of the CAI manner of theory training were presented before the student reported to an Education Center for his follow-on laboratory training. This division in time was a significant change from the normal training sequence in which laboratory learning experiences were designed to support the theory (or lecture) experiences that the student had in the classroom.

During 1966, several CAI courses were developed for teaching the theory. Extensive testing was performed to measure the relative performance of the students trained by the CAI with follow-on lab compared to students trained in the conventional lecture and lab situation. This type of CAI training was shown to be successful and in several of the courses significant reductions in training time resulted by applying CAI in this manner.

Since one-half of the Field Engineering training involves laboratory work (hands-on training), use of the same CAI terminal to control students working on simulated laboratory exercises was also explored. Computer programs simulated the experiences a trainee would have if he were working on the actual laboratory equipment. We found that simulated laboratory exercises were successful when the situation simulated involved the use of familiar test equipment, and the student had had previous practice in performing complex psychomotor skills similar to those required by the simulated exercise. Research studies demonstrated that Computer Assisted Instruction was an effective method of providing the Customer Engineer with training at his own branch office on a variety of subjects.

Today, Field Engineering has a nationwide network consisting of a central computer with over 300 remote typewriter terminals located in branch offices throughout the United States. There are currently over 70 courses offered through this system. We have developed a MACRO LIBRARY and CONTROL PROGRAM that provide authors with standard presentation routines for teaching segments, review segments, remedial segments, quiz administration, and quiz critique.

We are hopeful that as new display terminals with large screens and response probes are developed, our laboratory simulation training might be improved through more realistic simulation and decreased student time. Perhaps most of our computer system laboratory training can be simulated using CAI terminals.

We are also moving toward combining our theoretical training with simulated laboratory exercises, thereby providing practice for the Customer Engineer in applying newly acquired knowledge to the solution of simulated real-world problems. It is our hope that in so doing we can produce more effective learning by combining problem-solving (simulated trouble-analysis) experience with theoretical material. We are also investigating the need for providing higher-level language that will allow an author to more readily prepare both tutorial sequences and simulated laboratory exercises, eliminating the need to learn the symbolic programming language now used.

Through our existing CAI system Customer Engineers receive significant portions of their training in their branch offices. However, we are pursuing research and development to improve our use of the computer in training and to improve our authoring techniques and to continue to explore new areas of application.

L. R. O'Neal
Advisory Education Specialist
February 16, 1970

Computer Based Education Research Laboratory
University of Illinois at Urbana

Since its initiation in 1959, the PLATO program at the University of Illinois has been committed to exploration of the educational possibilities and the engineering-economic problems relating to the introduction of the computer as an active element in the instructional process.

The basic premise of the program has been that the existing technology of the 1960's was not capable of providing a significant and economically practical contribution to the nation's educational program. The goals of PLATO have therefore been twofold: first, to investigate the potential role of the computer in the instructional process; second, to design an economically and educationally viable system incorporating the most valuable approaches to teaching and learning developed in the investigation.

During the past nine years three systems (PLATO I, II, III) were designed and built, each embodying improvements indicated by the previous model; a network of four associated demonstration centers was added early in 1969. Exploratory educational efforts with PLATO systems have now involved experiments in at least twenty fields of study and over 100,000 student-contact hours at all levels. PLATO I and II stimulated research and development leading to the broader capabilities of PLATO III which was designed for optimum educational versatility without specific concern for costs. PLATO III, in use since 1964, has provided opportunities to develop many powerful new teaching strategies in various diverse fields. Currently, work is being undertaken on the design of a PLATO IV, a large-scale system which, even in a prototype version, would be justifiable in economic terms.

The designers of the PLATO system are concerned with the economical implementation of the system as well as its educational capability, and these two aspects are their chief considerations. In the educational realm, there has been progress far beyond the role of the computer as a bookkeeper, scorekeeper and guide to selected textual material. The student is not only helped in acquiring new information but he is also aided in fitting that information into a broader context and in gaining new perspective. Major computer-based systems such as PLATO provide a whole new capability for testing, evaluation and model-building for the learning and teaching process. Moreover, teaching with the PLATO system can be extremely varied since laboratory as well as classroom work is possible.

Evaluating educational effectiveness is still difficult since the data sample is limited. For a typical course, data on PLATO III have been limited to several hundreds of hours of student instruction. However, the results so far have been"most encouraging" and two conclusions seem justified:

1. That computer-based education is a plausible approach to improved individualized instruction in a very wide array of courses or subject material areas.
2. That the nature of educational testing and evaluation requires,and will be radically affected by, the availability of large computer-based education systems; a valid measure of effectiveness calls for a much larger sampling of data and a longer period of comparison than has heretofore been available.

Those developing and implementing PLATO visualize a particularly valuable role for computer-based education at the undergraduate level at universities, four-year colleges, and community colleges. They believe that a computer system would assume a widely varying fraction of the instructional load. In certain instances, such as introductory courses in computer science, mathematics, basic anatomy, or genetics, a PLATO-type system might well assume the entire load. In addition, there would be many courses in which the computer-based system would share the load more or less equally with human teachers. Faculty instructors could spend more of their time in advanced or interdisciplinary seminars in which the discussion of human values or the development of new ideas would occupy the entire teacher-student relationship.

In the second major area, the economic sphere, presently available CAI systems (including PLATO III) entail total costs which range between $2.00 and $5.00 per student contact hour. The PLATO IV system is intended to reduce this cost by approximately a factor of ten, to about 35 cents per student-contact hour; this figure is comparable to the lowest instructional costs in elementary schools and considerably less than comparable costs at colleges and universities. From a budgetary standpoint, then, the operational cost of the computer-based education system corresponds to the direct instruction cost in the conventional setting. With regard to the separate item of software, the PLATO III software system was designed with a special view to reducing the overall effort and associated cost of materials preparation.

The design of PLATO IV envisages a computer-based system which could reduce the total cost per student-contact hour by a large factor below that of any system currently available while maintaining the unique student terminal and system software capabilities demonstrated in PLATO III. In summary, the costs for the installation of the computer(including systems software) and the management of the computer center would total approximately $1.2 million per year, or about 15 cents per student-contact hour. If a comparable amount were associated with the rental of the student station and associated communications lines, the hourly cost for individual student instruction would be less than 35 cents per contact hour.

The cumulative and overwhelming trend of exploratory research results with the PLATO III system suggests that this new medium will be educationally effective and enthusiastically received by students at all levels of age and experience. There is every evidence thus far that this enthusiasm is shared by teachers and authors as well.

Adapted by Project CLUE staff from a Progress Report on the PLATO Program prepared by D. Alpert and D. Bitzer

Reference

Alpert, D. and D. L. Bitzer. "Advances in Computer-Based Education," Science, vol. 167, March 20, 1970, pp. 1582-90.

The Computer Assisted Instruction Laboratory
Center of Studies and Applications in Advanced Technologies
(Centro Studi e Applicazioni in Tecnologie Avanzate)
Bari University, Italy

The Center of Studies and Applications in Advanced Technologies (C.S.A.T.A.) was established in May 1969 and operates at Bari University. It is supported by several Italian agencies and industries interested in promoting research and development activities in the south of Italy.

A major interest of the C.S.A.T.A. is the development of instructional and research programs in the computer science field. These programs concern two closely related aspects: exploration of the use of the computer in education and the development of materials explaining how the computer is used in education. The CAI laboratory makes use of the C.S.A.T.A. equipment including IBM 1130, 1800 and 360/65 computers. There is a continual effort to coordinate closely the research and development programs of the CAI laboratory with the Center's more general activity in the computer science field. Thus, the laboratory utilizes when possible the methodologies of all other research groups operating in C.S.A.T.A., namely, the group developing information storage and retrieval techniques, the group working on numerical and statistical analysis automation, and the group investigating pattern recognition techniques and methods.

Research at the CAI laboratory focuses on three important aspects of the computer's role in education: as an administrative device, as a logical and computational tool used by technical-professional people, and as a direct factor in an instructional system. Thus, at the laboratory, the term CAI is used in its broadest sense and takes into consideration functions common to other computing systems, for example, storing, retrieving, processing, disseminating and creating information.

Staff have conducted courses for undergraduate and graduate students, outlining the basic logic of data processing systems, programming languages (PLI, FORTRAN, Assembler) and some of the basic methodologies of the information sciences (numerical analysis, simulation, mathematical programming, methods of information managements).

Staff members working on instructional use of the computer for computing are concerned with the development of conversational systems and mathematically oriented languages. At present they are researching a) a conversational system for experimental data processing; b) a language for formal computation; c) a language for mathematical programming; and d) the definition and the carrying out of a new conversational system for automatic numerical analysis and of procedures for formal computation. The results of these activities may provide the foundation for using the CAI system for problem solving and simulation in University curricula.

Instructional use of the computer as a medium is being explored with attention focused primarily on the purely technological aspects of: defining suitable languages for the student-machine interaction and their use in some experimental applications, implementing more flexible methods of analyzing student response and developing methodologies for course management. The student-computer interaction is accomplished through a language by means of its text-processing, diagnostic and computational functions. The different kinds of languages actually used belong to two main classes -- computational and text processing. Staff at the C.S.A.T.A. laboratory have studied two languages belonging to these classes (Coursewriter III and APL).

Staff at the CAI laboratory define three general areas of research and development which they intend to explore in the future:

1. Computer Science and Instruction
   a) the inauguration of training programs for computer technicians and users
   b) the development of new undergraduate and graduate degree programs

2. Instructional Use of the Computer for Computing
    a) the development of suitable facilities and prototypes of use in courses to facilitate convenient computing for students
        - using APL, FORTRAN, PLI for problem solving
        - using APL in simulation laboratories
    b) the establishment of a research center and consultation services to facilitate general student and faculty use of advanced application packages in all schools of the University
3. Instructional Use of the Computer as a Medium
    a) the development of system programs
    b) the development of a demonstration center for instructional techniques and course strategies
    c) the development of expertise in computer managed instruction by means of a prototype course development project
    d) establishment of a center for instructional evaluation.

Adapted by Project CLUE staff from a report prepared by Professor A. Romano for the IFIP World Conference on Computer Education 1970

CAI Laboratory
The University of Texas
Austin, Texas

The University of Texas CAI Laboratory has been involved in a broad spectrum of research and development activities. Two principle research efforts have been in the areas of aptitude by treatment interaction (a two-year contract with the Advanced Research Projects Agency of the Department of Defense) and a five-year research program on instructional design, authoring systems, and learner control (sponsored by the National Science Foundation). Development activities have included curriculum development, the development of a remote terminal network, and the development of interdisciplinary graduate training programs for instructional designers and instructional researchers, especially between the departments of computer science and educational psychology.

Research on Cognitive Abilities and Learning: This research, concerned with the interaction between cognitive traits and instructional treatments, has been conducted at both a basic and an applied level. At the basic level, we seek a set of theoretical cognitive constructs which will account for individual differences both in measures of learning and in measures of performance on cognitive aptitude test items. Through these cognitive constructs, we hope also to account for the interactions between aptitude patterns and variations in instructional treatments. At the applied level, we seek prescriptive information, ultimately based on validated theoretical constructs, which can guide the instructional designer in the production of computer-assisted instruction (CAI) sequences tailored to the relevant trait patterns in his population of learners.

Since a set of prescriptive principles for the use of aptitude by treatment interactions (ATI) in instructional design is currently not available we have accordingly never consciously implemented an aptitude by treatment branch in any "real" CAI program. Instead, we adjust instructional treatments constantly on the basis of moment-to-moment response topography. Nevertheless, since we are faced with the task of producing quality computer-based instructional programs, often under contract, we must provide the instructional designer with some form of guidance even in the absence of theorems of instruction. Our approach has been to give him a pragmatically useful "instructional design model" (Bunderson, in press) which serves as a quality control and management system for CAI program development. This instructional design model prescribes a sequence of activities, each of which produces a specified design product useful in quality control. The model provides a systematic structure within which hunches, heuristic guides, intuition, and other presently non-specifiable bases for designing certain variations into instructional sequences can be channeled and made subject to quality tests. The primary factor in quality control is the intensive use of student feedback at all stages of program development. By a time-consuming iterative process of testing and revision, an efficient program, adaptive to a wide range of individual differences, can be developed.

At the more applied end of this project, then, we seek ways of defining "treatments" and "aptitudes" as variables which can be defined and manipulated not only by the laboratory researchers but by the instructional designer who works with the guidance of the design model. At the other extreme, we seek through investigations employing laboratory concept and rule learning tasks, and well-known cognitive abilities, to tie our efforts to the body of research and theory in the psychology of human learning. Studies employing the "Science of Xenograde Systems", an imaginary set of concepts and rules about the behavior of an atom-like lawful system, represent the more applied efforts within this project, while studies employing concept problems, pair-associate lists, and other laboratory tasks, represent the other effort.

In the case of either task, the approach we take is the same. First, a careful analysis of the task in terms of its requirements for efficient information-processing is undertaken. This analysis forms the basis for specification of cognitive aptitudes most likely to be related to the task requirements, and of treatment variables which might alter the task such that the relationship of certain aptitudes to performance can be changed in predictable ways. Predictions derived in this manner are then tested experimentally.

NSF Sponsored Research Program in Instructional Design: The emphasis of this program of research, now in its second year, was summarized in the abstract to the initial proposal.

> Engineering groups in both academic and industrial laboratories are working to bring about cost breakthroughs in hardware, i.e., memories, student terminal devices, and communications. The University of Texas Computer-Assisted Instruction Laboratory is working to bring about significant improvements in both costs and effectiveness in authoring systems, i.e., instructional design, instructional theory, and computer aids to authoring. The so far elusive cost-effectiveness benefits of CAI will not be realized until advances both in hardware and authoring systems are achieved.

A spectrum of R & D activities from the basic to the applied has always been a feature of the CAI activities at the University of Texas. It has been felt that the questions asked in learning and instructional research should be influenced by the needs of instructional designers for theoretical and empirical guidelines. It has been felt that systems research and development from the computer-science side should also be influenced by the needs of authors and instructional designers, and by the findings of learning and instructional researchers. Projects undertaken in support of these program aims can be summarized according to the following outline.

I. CAI Program Design as Influenced by Modular Programming

  A. Definition of Program Structures for Different Content Areas
  B. Design of Author Input Systems for Defined Program Structures
  C. Evaluation of Costs and Benefits of Alternate Designs

II. Research on Learner Control and Task Structure

III. Systems Research and Development

  A. Research Toward Natural Language - CAI
  B. Software to Generate Course Code from Author Input Systems
  C. Toward the Design of a Better CAI Author Language

IV. Studies in Implementation

  A. CAI in College of Education Academic Programs
  B. A Remote Terminal CAI Service Facility

This outline is designed as a heuristic device to reveal the logic of our activities under this program as well as to summarize projects. Thus,it will be seen that some projects fall under more than one heading, depending on the stage of their development. For example, a modular program structure in a specific content area may lead to the definition of a paper and pencil or on-line author input system, which may lead to a preprocessor for producing the CAI code.

A theme of the research effort at the University of Texas (UT) has been that cross fertilization between computer science concepts and methods and education (instructional design and educational psychology) will lead to decisive improvements in instruction for students, and toward the definition of a new "hard discipline" of education which will produce ultimately a new set of education professionals. Projects completed or underway as of September 1970 are summarized in a recent report (Bunderson, Simmons and Judd, 1970)

Developmental Activities: The emphasis on instructional design for CAI and its psychological and computer science foundations at the University of Texas has helped attract curriculum development contracts from publishers, computer manufacturers, and federal agencies. The most successful projects have been in freshman mathematics, English, and chemistry, prevocational training for the educable retarded, and the Arabic writing system.

A network of terminals in up to nine schools and colleges in Texas and Louisiana connected to the Laboratory's IBM 1440 computer in 1968-69 led to plans for broader implementation. Consequuntly an attempt was made during 1969-70 to implement Coursewriter III and APL on the IBM 360/50 computer used by the University of Texas for business data processing. This complex system was successfully implemented and was in operation in the spring of 1970. As has been the case with other R & D groups in this country, the CAI Laboratory experienced substantial cutbacks in funding for 1970-71 and had to terminate this promising project in June of 1970. Fortunately, CAI capabilities on the CDC 6600 computer housed in the University's computation center are increasing rapidly, and through NSF funding a regional network for computation, including CAI, is being established.

References:

Bunderson, C. Victor, The Computer and Instructional Design, in Wayne H. Holtzman (Ed.) Computer-Assisted Instruction, Testing and Guidance. New York, Harper and Row (in press)

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Computer Support of Individually Prescribed Instruction
Learning Research and Development Center (LRDC)
University of Pittsburgh

The goals of a recently initiated project at the Learning Research and Development Center (LRDC) are: to study how the computer can best support a school designed along the lines of individually prescribed instruction (IPI); to integrally incorporate CAI lessons into the rest of the school program; to determine how much support a small computer such as a PDP 15 can provide in an individualized elementary school; to ascertain what functions it can perform as a stand-alone configuration; and to estimate the possibilities of using it as a satellite system in a computer network, in which a large scale computer performs the major data processing tasks required.

The new project at LRDC is an exciting effort to integrate two major research and development areas, IPI and CAI. Since 1964, LRDC has been developing and testing individually prescribed instruction (IPI) at the nearby Oakleaf Elementary School. The IPI work involves curriculum design, text development and specifications for management procedures and has already become widely known.

For some time the IPI project has used a remote computer, but toward the end of 1969, staff began assembling a small local computer facility for the Oakleaf School. When implemented, the facility will provide: 1) a computer management and information system; 2) a computer-administered, criterion-referenced testing system for the guidance of students through the curriculum; 3) computer-administered exercises for basic skills and concept learning to supplement the other educational resources of the school; and 4) data for curriculum research and improvement.

It has been difficult to incorporate CAI lesssons into the rest of a normal school program, but this problem disappears in an IPI school which provides individualized educational environments at all times. Economics is an important consideration, but the cost of computers continues to drop while the ability of school staff to use computers effectively increases. For example, a PDP 15 today is half as expensive and twice as fast as the corresponding model of the same size in 1965.

In the area of computer technology, there are two major problems for which the project seeks solutions: 1) What should be the distribtuion of computer power between locally situated and necessarily small devices and the large and central computers? 2) What should be the nature of the interface between user and system in terms of the number and types of terminals required, the interactive quality necessary for efficient student and teacher transactions with the system, and their location in the school?

Using terminals in the school which operate remotely on the PDP 7/9 at LRDC, the staff will test the hypothesis that a small local computer could support a terminal network at the school that would provide computer-based testing and basic information for teachers to monitor and plan student progress. This small computer might also present CAI lesssons developed for teaching specific objectives within the IPI system.

It is not possible to discuss results at this date since the CAI component commenced only in the fall of 1969. However the staff at LRDC anticipates that the small local computer will provide the required responsiveness, flexibility for adding new terminals, economy for line charges when a central computer is required, and local administrative control so that the computer can be schedulded to accommodate the needs of the particular school. The successful installation of computer support for IPI will increase the flexibility of the IPI procedures which are so necessary in such curriculum areas as science and social studies.

Adapted by Project CLUE staff from a paper by William Cooley in *Journal of Educational Data Processing,* 1970, 7, 18-28.

Project IMPACT
HumRRO
Alexandria, Virginia

Project IMPACT (Instructional Model Prototypes Attainable in Computerized Teaching) is an integrated, multidisciplinary CAI effort. It was initiated by the Human Resources Research Organization (HumRRO) under initial sponsorship of the U. S. Army. The objective of the effort is to evolve, through cyclical development and evaluation, an effective, efficient and economical computer-administered instructional system.

Problem areas addressed include computer system capabilities, CAI language needs and potential, and of prime importance, the meaning of instructional strategies and their relationships to learning processes. The professional staff (presently totalling 18) includes specialists in behavioral science, electrical engineering, computer software, instructional programming, and applied mathematics.

Rationale

CAI is the leading operationally defined edge of a model for individualizing instruction. It represents the potential for accomplishing a quantum leap in adapting instruction to the momentary needs and capabilities of the individual student. The capacities of modern computers clearly provide some of the prerequisite tools: vast storage, rapid processing and retrieval, precision of control, and extended communication. But mere presence of these tools in an instructional system is no guarantee of improvement. The total instructional system must be taken into account. The problem for any instructional agent (human or machine) is to take optimal action in line with an overall "best" strategy for transmitting uniquely relevant information to the student. Of necessity, recurrent decisions concerning these instructional actions must be made relative to 1) the subject-matter being taught, 2) the specific student, 3) the momentary circumstances and 4) the available options (communication channels), if specified proficiency criteria are to be attained effectively and efficiently.

The potential of CAI will only be realized with a systematic, persistent, and iterative scientific effort leading to a synthesis of principles into a potent model of the instructional decision process. With this realization the new system of instruction can be molded into a cost-effective system. IMPACT addresses itself to furthering this realization.

Approach

The total instructional system noted above is considered in Project IMPACT over four phased development cycles. The heart of this total system CAI effort is the iterative development and testing of instructional decision models (IDM's). This cyclical approach takes shape in a cybernetic system in which the set of control processes continues to be refined from the input (student data) and output (criterion performances) relationships of the successive IDM's. Within any given version, these control processes are embodied in the particular decision-making rules incorporating system experience gained up to that point.

Over the four cycles of development and testing, the four prongs of the effort (hardware, software, subject-matter and IDM) are revised and updated. The first two cycles comprise respectively the development and evaluation of the "breadboard" (preliminary) CAI system. Synthesis and implementation of the refined components into a prototype, operational CAI system is to be undertaken in cycles three and four.

Progress

General: The first cycle, assemblage and shakedown of the "breadboard" system, is now almost complete. Limited numbers of students are continuing to be run in order to "debug" all components. Extensive data collection, evaluation, and revision of this preliminary system is scheduled to begin in July of this year. A film describing the IMPACT approach has been developed and is available upon request. Detailed accounts of the initial, technical developments are listed at the end of this note. One major difficulty encountered has been a funding reduction which has led to a slowing of the overall progress of the effort. To help compensate for this a major activity has been preparation and submission of proposals on decision modeling to potential sponsors other than the Army. To date this has resulted in additional support from the National Science Foundation and the James McKeen Cattell Foundation.

Specific: a) A first-cut, minimally sophisticated, IDM has been designed, programmed, and awaits evaluation (see Seidel, et al, 1969 (b)). Factors currently included are 1) general and specific pre-course student characteristics of education, aptitudes and achievement, 2) within course history of momentary and cumulative progress, including motivational indices, and 3) mapping of subject-matter structure. The initial IDM incorporates estimates of student-confidence and use of student inquiry (through a glossary technique).

b) The main frame of the hardware is an IBM 360/40 with 256K core, a 2314 disk drive, and high speed card reader, punch and magnetic tapes. The provisional configuration includes completed construction of twelve functioning student stations with Sanders CRT and visual projector allowing single frame or variable speed, motion presentation (Perceptoscope). The standard response capability is keyboard and light pen. As part of the effort to expand channels of communication between student and the instructional decision model a preliminary, operating version of a speech recognition system has been added to one terminal. Efforts are underway to refine the system for multiple speakers and to expand the vocabulary capability from 25 to 100 words. Ten specially constructed interface controllers are currently being installed to permit integration of the display devices from different manufacturers. Hand-printing capability using an electronic pencil on a Sylvania Tablet has been experimentally installed in one student station.

c) A COBOL course had been developed in three levels as the instructional content for cycle one. Debugging and implementation of a course and decision model within the computer system is currently being accomplished. A short, self-contained course in Authoring Techniques has been developed.

d) Modifications to Coursewriter allowing compatibility with a CRT operating system have been implemented. A set of supervisory programs and subroutines (called Zeus) have been designed and implemented to handle I/O, command processing, task switching, and other details for Coursewriter in the IMPACT system. A set of Authoring commands has been developed and implemented. A system of programs for off-line text manipulation and control has been designed, programmed and implemented, as has been the IMPACT Data Evaluation System (IDES) for retrieval, analysis, and summary of individual and grouped data. Modifications necessary to time-share multiple student-stations are being debugged.

Robert J. Seidel
Project Leader
February 24, 1970

References

Seidel, Robert J., et al. "Project IMPACT: Computer-Administered Instruction Concepts and Initial Development," HumRRO Technical Report 69-3, March 1969a.

Seidel, Robert J., et al. "Project IMPACT: Description of Learning and Prescription for Instruction," HumRRO Professsonal Paper 22-69, June 1969b.

Educational Technology Department
Bolt Beranek and Newman, Inc.
50 Moulton Street
Cambridge, Massachusetts 02138

The work of the Educational Technology Department is directed toward understanding and enchancing learning through appropriate development and use of computers. Staff members are knowledgeable in many areas of computer science including programming languages, computer time-sharing, man-machine interaction, computer-assisted instruction, and computer graphics. We have substantive educational involvements in many fields including mathematics, languages, medicine, English, physics, biology, psychology, flying, engineering and music. We have done work in educational testing, counseling, management, and administration, as well as instruction itself.

Recent projects have included research into the use of programming languages as a conceptual framework for mathematics teaching, the development of associated elementary, secondary, and teacher curriculum materials, the design of a system for clinical training in medical schools (and of associated medical case material), a survey of computer-assisted instruction, the production of a computer-animated motion picture, the engineering development of a teletype-mountable opaque projector for use with classroom demonstrations, the design and construction of a mobile teaching terminal with sensors and effectors, remotely controlled by a student's computer programs, the development of computer-administered conditional tests, the design of new computer languages (LOGO, MENTOR, SIMON) for instruction, and the development of a time-sharing system for educational management.

The activities of the Department encompass teaching, consulting, and research. Recent clients include the U.S. Office of Naval Research, the

National Science Foundation, the Advanced Research Projects Agency, the Massachusetts Department of Education, the American Can Company, the Medinet Department of General Electric, the General Learning Corporation, and the Lexington and Westwood School Systems.

Wallace Feurzeig
Director

Volume I - Appendix C

Samples of Instructional Programs and Their Use as Tools for Learning

This appendix provides five examples of computer use as a tool for learning. Typically the learner is introduced to an information processing procedure and its use within the subject being studied. He is invited to use it as he wishes; sometimes performance goals are specified for him. The emphasis in these examples is on the nature of the interaction and the pedagogical content.

An excerpt of a few pages from many hours of interaction between learner and computer cannot adequately represent a set of programs used thoughout a full course. The descriptions given here rely on an explanation of the purpose and method of the program, a description of typical use, and suggestions for expanded use of the program.

Because it is so difficult to represent materials for regular instructional use in a short space and within the confines of the printed page, the samples presented here have been reconstructed from real classroom use. In some cases the demonstration shown here came first and was followed by elaboration into a more substantial package suitable for use in classroom instruction. In the others, records of regular use as a learning tool were adapted for presentation in this appendix to make a point about student initiative, role of the computer, etc. In all cases the transcript of interaction between student and computer was produced by an existing program.

The set of samples in this appendix should be expanded to include various contributors and represent the full scope of computer use as a tool for learning. Many projects and organizations were invited to provide samples of instructional programs; none responded. On visits, staff collected some examples which were promising but too long and complex for this appendix. Five samples were then adapted from work by the project director to fill out the appendix, and selected projects were again reminded of the need for examples in the CLUE report. Just before printing time one other sample was received, but no in a form suitable for presentation.

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Send Comment to: 109 East Madison
Ann Arbor, Mich.
48104

1. Manipulation of Social Science Data: Voter Opinion Before and After the 1968 Election. (Political Science)

Introduction

This computer program is presented as a model for capabilities which can enlarge the options for supplementary course work in the inductive sciences. The program offers the student a research tool to use in investigating and interpreting data as he wishes, a possibility often not open to the student because of the expense and time required to collect and organize such material before analysis can begin. The procedure can serve the instructor as a teaching aid to stimulate discussion, motivate individual study, or provide a source of factual material for individual or class projects.

Use of the program with data on voter opinion before and after the 1968 national election illustrates how the data-processing power of a digital computer can be used to seek patterns and relationships otherwise hidden in large masses of factual information. In this case the data file was derived from interviews during the 1968 Election Survey conducted by the University of Michigan's Institute for Social Research; the same file is widely used by professors for political behavior research.

Objectives

The instructional package has three primary objectives: 1) To enhance the student's understanding of the theory, practice, use and limitations of survey statistics through direct involvement with real data; 2) To encourage the development of intellectual abilities used when uncovering and interpreting information which is effectively "new;" 3) To provide direct contact with a computer, at a level appropriate to the student's background and needs, as a worthwhile enrichment experience.

The program was prepared by Mark Barnett at the Center for Research on Learning and Teaching, University of Michigan.

Typical Use

An instructor describes for the students the purposes of the program and suggests how they might best use it to achieve objectives of the course. The conversation trace on page 4 illustrates the program's operation.

After signing on, the user identifies himself only if he wishes the instructor to be able to review his use of the learning aid through records stored automatically. The program then lists any announcements by the instructor. For the remainder of the session shown here, the program produces a series of tables as requested by the user through keywords selected from a special list naming data variables and tabular analysis.

Future

Changes in the program are being made constantly, for example to allow: 1) comparisons between responses of a supplemental sample with those of the national sample; 2) additional statistical computations; 3) automatic monitor of program use; 4) recategorization of original data; and 5) application to additional data-base with similar structure.

The future for this approach must lie in adaptations of the procedures and data structures to particular needs of each discipline or teacher, and ultimately to the needs and interest of individual students.

CONVERSATION TRACE: MTS SESSION WITH VOTER

```
MTS (LA05-0023)
#DATA CONCENTRATOR USERS COPY *DCNEWS
#signon sv20
#ENTER USER PASSWORD.
[redacted]
#**LAST SIGNON WAS: 15:32.46   06-02-70
# USER "SV20" SIGNED ON AT  15:41.46 ON 06-02-70
#source sv20:voter
#$SET ECHO=OFF
#EXECUTION BEGINS

 PLEASE ENTER YOUR NAME AS INSTRUCTED.
 ?  user
 INSTRUCTOR'S ANNOUNCEMENTS ARE PRINTED OUT HERE.
```

At present, any "name" will work. Capability is built-in for monitoring use of VOTER.

Instructor can maintain a short file of information for his students.

```
 ENTIRE OR STRAT?
 ?  entire

 VAR. NAME?
 ?  think win

 NONE OR SECOND VAR. NAME?
 ?  none

                          VARIABLE -- THINK WIN/

                HUMPHREY        NIXON      WALLACE        OTHER   REMAINING

   N = 1557   341=21.9%   887=57.0%     79= 5.1%       5= 0.3%   245=15.7%

 NEW, FURTHER OR SAME?
 ?  further

 NONE OR FILTER VAR.,INCLUDE OR REJECT,FILTER RESPONSES?
 ?  seen twice reject 3
 ?  none

 VAR. NAME?
 ?  think win

 NONE OR SECOND VAR. NAME?
 ?  none
```

Eliminates respondents who were not re-interviewed after the election.

```
                                     VARIABLE -- THINK WIN/

                HUMPHREY          NIXON         WALLACE          OTHER    REMAINING

   N = 1321    291=22.0%    760=57.5%      59= 4.5%       4= 0.3%    207=15.7%

 NEW, FURTHER OR SAME?
 ?

     same

 VAR. NAME?
 ?  think win

 NONE OR SECOND VAR. NAME?
 ?  thot win

                              HORIZONTAL VARIABLE -- THINK WIN/

                                VERTICAL VARIABLE -- THOT WIN/

   N = 1321     HUMPHREY          NIXON         WALLACE          OTHER    REMAINING

   HUMPHREY    182=13.8%      82= 6.2%      16= 1.2%       2= 0.2%      55= 4.2%

      NIXON     87= 6.6%    629=47.6%      30= 2.3%       1= 0.1%    101= 7.6%

    WALLACE      0= 0.0%       3= 0.2%       6= 0.5%      0= 0.0%       4= 0.3%

      OTHER      0= 0.0%       2= 0.2%       0= 0.0%       0= 0.0%       1= 0.1%

  REMAINING     22= 1.7%      44= 3.3%       7= 0.5%       1= 0.1%      46= 3.5%

 NEW, FURTHER OR SAME?

 ?  stop

 THIS PROGRAM NOW TERMINATES BECAUSE

 OF YOUR RESPONSE.  CALL AGAIN!

  STOP      0
#EXECUTION TERMINATED
#$SOURCE *MSOURCE*
#signoff
#OFF AT 15:46.50
#ELAPSED TIME        303.783  SEC.
#CPU TIME USED         6.682  SEC.
#APPROX. COST OF THIS RUN    $.81
```

About 5 minutes to get 3 tables at a cost of 81¢ during prime time (high use) for the system

2. Experience with a Simulated Economy: Integrating Theory and Policy Planning.(Economics)

Introduction

The use of a macro-economic policy game is extremely effective in bridging the wide gap between artificial economic theory and the real problems of economic policy. Rather than leaving the student with two separate segments of understanding and little notion of the interrelationship of theory and policy planning, the game is designed to convey to the student an appreciation of the real world situation in which the economic policy maker finds himself. In an environment of uncertainty regarding the future and the linkages between his policy tools and his ultimate goals, the student, like the actual policy maker, must select a policy mix which will best accomplish those goals.

The game is not a substitute for, but a supplement to, the other course material. The best model for game use is one which is sufficiently complex to include the important dynamic characteristics of the actual economy and, at the same time, is simple enough for the instructor to feel that he fully understands its behavior.

Objectives

The primary objective of the game is that the student learn to apply his economic theory to solve his economic policy problems. He should be faced with the same kinds of uncertainties, conflicting goals and other economic problems that confront the actual policy maker in the real world,yet at the same time have the assurance that a consistent model similar to the ones he has seen before is directing the behavior of the game economy.

It is intended that the student view his game world as the policy maker sees his real one: a set of statistics, ordered by unknown forces, on the basis of which policy decisions must be made. He uses the theoretical tools at his disposal to analyze the data as best he can, makes an irrevocable decision for which he is held accountable, and learns from his mistakes as his economy advances over time and responds to his actions.

Robert S. Holbrook, Department of Economics, University of Michigan, prepared this model, with assistance by Richard Kopcke, and derived it from one developed by R. Attiyeh, University of California at San Diego.

Use

The model represents a world composed of ten essentially equivalent countries. In each country, consumers and business firms are assumed to regulate their spending behavior according to income, prices, interest rates, etc., while the policy maker has control of taxes, government spending and the money supply. A feature of this model which distinguishes it from other models of a similar type is that the ten countries are interrelated through international trade and capital flows.

The students in the class are divided into ten groups (three or four students in each) and each group is responsible for policy in one of the countries. Their goal is to achieve the best possible degree of full employment, price stability, economic growth and balance of payments equilbrium. To do this successfully requires that they understand the workings of their own economy and be able to forecast its behavior.

At the beginning of the game the students are provided with a set of historical statistics for their economy. These data trace the behavior of their economy for the preceding four years and provide them with the sort of information available to the typical economic policy maker. Each group attempts to analyze the past behavior of their economy, using the relevant tools from economic theory, and on the basis of such analysis they formulate a policy decision which takes the form of changes in government spending, taxes and the money supply.

Any actual decision is implemented at one of the computer terminals on the campus. Once a student group has accessed the computer and called the program, the computer immediately asks the group to enter its economy number and its policy decisions for the following quarter. The students key in this information; the computer reprints it in full detail and allows the students an opportunity to change their minds or correct a mistake. If they signal that their decision is correct as printed, the solution program utilizes their decisions, together with other predetermined information, to solve for the new values of all relevant variables. It stores these new values in a file reserved for that particular economy and also prints them out for the students at the terminal.

Experience with the simulation is tied in to real world events in policy planning and also economic theory by discussions among students and with the instructor. To obtain full value the computer-based exercise is interpreted and tested outside the artificial gaming situation.

Future

There are a variety of modifications which could be made in such a program as well as alternative uses to which the model could be put in the future. Stochastic elements could be included in the equations of the model, thus adding an additional element of uncertainty to policy making and rendering the game more realistic. The stochastic version of the game might also be used as a source of statistical, or econometric examples. Since the model produces an essentially unlimited array of statistical data, examples of almost all real world econometric problems can be found.

```
LOHR                    GNP ACCOUNTS

     REAL    REAL    REAL   REAL     REAL     NOM      REAL                    REAL
QTR  GNP      C       GFI   INVCHG    G       GOV      CCA      K        L      T
21  665.1   455.7   94.8    -2.6   117.2   136.0     59.1  2118.0  70.40   96.3

  REAL   REAL   NOM
   YD     RF     M        R       U    PCHG     P       TO      T1      INV     W
485.5   24.2   145.0   7.52   5.11   1.91   1.166  -22.0   0.190    33.3   265.

TYPE 'YES' IF YOU WANT TO TRY ANOTHER QUARTER.
yes
```

An unacceptably high unemployment rate prompted the student to make adjustments which he felt would lower it.

```
INPUT ECONOMY NAME AND CHANGES IN VARIABLES GOV, M, TO, AND T1.
```

Significant changes made in three of the four parameters produced the desired reduction. Note, however, concomitant changes in other variables — particularly interest rate (R) and price level (P) — whose long term effects may produce an increase in unemployment.

```
lohr
3
5
0
-.03
IN ECONOMY LOHR             YOU HAVE ADDED
   3.0    TO NOMINAL GOVERNMENT EXPENDITURES
   5.0    TO THE NOMINAL MONEY SUPPLY
   0.0    TO THE INTERCEPT OF THE NET NOMINAL TAX FUNCTION
  -0.030  TO THE MARGINAL NET TAX RATE

IF YOU DETECT AN ERROR IN YOUR INPUT TYPE 'ERROR'


LOHR                    GNP ACCOUNTS

     REAL    REAL    REAL   REAL     REAL     NOM      REAL                    REAL
QTR  GNP      C       GFI   INVCHG    G       GOV      CCA      K        L      T
22  730.9   515.7   87.3     8.7   119.2   139.0     59.3  2126.9  70.68   88.6

  REAL   REAL   NOM
   YD     RE     M        R       U    PCHG     P       TO      T1      INV     W
556.1   26.9   150.0   8.10   2.50   0.59   1.168  -22.0   0.160    35.5   317.
```

3. Experimentation with an Ecological Model: Management of a Natural Living Resource; Exploration of Models for Description and Prediction. (Natural Resources)

Introduction

Learning situations involving models, simulation and computation have been explored in many areas including economics, biology, chemistry, physics, sociology, political science and psychology. This sample was prepared for a demonstration in resource management and has been used in class instruction ever since. The most interesting pedagogical feature should be the natural and beneficial relation between the use of the computer as a training device and its use as an aid in scholarly research or on-the-job performance.

The student who becomes familiar with the use and the process of mathematical modeling has acquired a powerful intellectual tool. Students who have used this modeling exercise report quite favorably on its stimulation of interest and promotion of skill and understanding.

Objective and Procedure

The exercise is designed to give a beginning student practice in managing a simulated fish population and in manipulating the underlying ecological model. Such a research tool offers students at the introductory level an opportunity to model processes ordinarily beyond the reach of their analytical tools and patience for tedious computation.

The task for the student, acting the role of a fishery manager, is to build up and maintain a salmon population in a way which maximizes the catch taken by the fishery. He may establish for each year the minimum catch or the escapement (the number allowed to swim up river to spawn). Values of catch and escapement for several preceding years are provided as background data.

This program was prepared by Karl L. Zinn from a model and teaching situation developed by James T. McFadden, School of Natural Resources, University of Michigan.

After "managing" for a five-year period (barring complete destruction of the population while doing so), he is given a summary of fishery success and may decide to start over (set time back to 1970), continue working for another five years, or stop the game to define what he thinks is the best management strategy. The "game" for the student is to discover the model and work out a good strategy for managing the fish population.

The underlying model for this simple game is an equation defining the run, the total population available for catch or escape, in terms of the previous year's value of escapement (number available for spawning). Management by setting the escapement near the level of a parameter called PEAK is the optimum strategy for the initial model. A proctor or another student can reset the parameters of the equation to change the model and make it a fresh exercise for those who have not yet seen or analyzed the equation. Presently the program permits a student to list and examine the model only after he has described a strategy quite close to the optimum one.

Description of Typical Use

The learner begins in the role of a manager of a fishery located at the mouth of a river. Usually he already has considerable knowledge of ecology, maintenance of populations and sound management techniques, but this is the first test of his ability to apply that knowledge.

The teaching assistant establishes the connection between the terminal device and the main computer. He requests the file which describes the population model and the management game situation. He has the option of determining the model and parameters of the initial management game before turning the terminal over to the student.

The PIL translator prefaces each line by an "=" to show it is ready to receive instructions or data values. The proctor selects an alternate version of the model (#90) and changes the parameter which determines the value of escapement for a maximum catch (15,000). All numbers are expressed in thousands of fish for user convenience.

```
= SET model=90
= SET peak=11
```

A standard model is used for demonstrations, introductions, and certain practice. The user (proctor or student) may also select other models by number (90 - 98, since these are the program "parts" in which models presently are stored), or ask the computer to select one of the available models at random. If he types USER, the system queries him for the parameters of the model, or he may type instructions which define his own "part 99." In this way the proctor or teaching assistant may set up special conditions for any student, or one student may set conditions for another to play the game.

The proctor tears off the paper (or erases the CRT) to hide the crucial information about the underlying model from the player of the game and types "go" to indicate to the PIL translator it should begin the procedure.

```
= GO
HISTORY
YEAR           CATCH           ESCAPEMENT
1967           13.169            4.830
1968           12.938            6.730
1969           12.083           14.683

WHICH MANAGEMENT STRATEGY DO YOU WANT TO ADOPT:
```

This student decides to assure a minimum catch and indicates his selection of that strategy.

```
= catch

YOU MAY CHANGE YOUR STRATEGY AT THE END OF ANY 5-YEAR PERIOD.  NOW IN
THOUSANDS OF FISH ENTER YOUR SELECTED CATCH FOR 1970.

= 16

CATCH = 16.000
ESCAPEMENT = 2.000
ENTER YOUR SELECTED CATCH FOR 1971

= 10

CATCH = 10.000
ESCAPEMENT = 1.000
ENTER YOUR SELECTED CATCH FOR 1972

= 5

NONE ESCAPED:  START OVER.

BY WHICH STRATEGY WILL YOU MANAGE FISHERY: ESCAPEMENT OR CATCH?
```

He learned this lesson quickly and will next try the more cautious strategy of assuring that a minimum number escape to spawn. Actually he could have managed well enough by setting catch had he studied the history and made some inferences about this population.

```
= escape

1970 ESCAPE =
= 8
```

The student had to face up to a "simulated" failure for the fishery. He goes on to apply now some of the concepts he had read about and discussed.

After five years of harvesting (not shown here) he is reminded of fishery economics, and invited to break out of the game.

```
1974 ESCAPE =

= 11

CATCH = 15.000
```

```
FIVE-YEAR SUMMARY
TOTAL = 67.000
AVERAGE = 13.400
DO YOU WISH TO BEGIN AGAIN, CONTINUE, OR DEFINE OPTIMUM STRATEGY?

=continue
```

This student gains another five years of experience which is concluded again by a summary and reminder. This time he is ready to discuss the game.

```
= define

STRATEGY =
= escape

OPTIMUM =
= 11

FOR ESCAPE LEVEL SET AT 11.000
CATCH SHOULD AVERAGE ABOUT 19.000
19.000 IS THE BEST ONE CAN DO ON THE AVERAGE
YOUR ACTUAL PERFORMANCE FOR THE TRIAL SESSION WAS
ENTIRE = 150.000
AVERAGE = 15.000
```

If the student had not prescribed a reasonable optimum for the strategy of his selection, the program would have referred him back to the game for further practice. Had he selected the strategy of determining the catch in advance of the fishing season, the program would have reminded him of the difficulties of this approach.

Once the student has demonstrated mastery of the management task (within the loose tolerances of this simple game and the keyword checking in a short dialogue not shown here), he is invited to examine the model underlying these simulations.

```
DO YOU WISH TO SEE THE MODEL UNDERLYING THIS GAME?

= yes

    90.1  SET RUN=2*MAX*ESCAPE/PEAK-MAX*(ESCAPE/PEAK)**+8*RN OF ERROR-4
    90.2  IF RUN<MAX/3 $AND ESCAPE>PEAK, SET RUN=MAX/3
    90.3  IF RUN<0, SET RUN=0.

MAX = 30
PEAK = 11
```

```
FOR FURTHER EXPLORATION OF THE MODEL YOU MAY CHANGE PARAMETERS.
TYPE, FOR EXAMPLE, SET MAX=40.
```

He can then revise the model in order to play the game again, or more practically, simply display the relations and error distributions according to the chance factors included in the model.

```
= FOR I=1 TO 5, TYPE IN FORM "___.___", 8*RN OF ERROR - 4.
  1.327
 -2.552
  0.118
  3.195
 -1.970

= FOR ESCAPE = 9 TO 13: DO PART MODEL
ESCAPE   RUN    CATCH
 9.000  25.091  16.096
10.000  28.113  18.113
11.000  32.456  21.456
12.000  29.589  17.589
13.000  27.282  14.282
```

A number of students demonstrate considerable confidence with the computer as a research tool, modeling rather complicated processes ordinarily beyond the reach of introductory level students.

Future

The sample described is only an introduction to the approach. The models given to students in resource management are much more complicated, even at the research frontier of the discipline. Projects completed by advanced students have contributed to the research program of the professor using models for instructional purposes.

The work of advanced students on population models is directed also at use in management games for instruction of beginning students. A number of natural living resources have been simulated, but operational, economic and political components of a realistic game have not been developed yet.

Sampling procedure and statistical routines should be added by which the student obtains information about the population. He is given finite resources for measurement and control activities, and might spend them unnecessarily on excessively accurate determination of the population status at one time. The management decisions of the student affect not only the population, but also the attitude and actions of many persons concerned about the particular natural living resource. For example, in the simple salmon fishery game the program responds "Fishery is concerned about the low catch" when the manager lets it fall as low as 5,000. Economic and political aspects of the models will be expanded.

4. Assessment of Written Expression: News Stories (Journalism)

Introduction

The fundamental nature of computers is as appropriate for manipulation of characters used in written expression as for operations on numbers used in mathematics. Although automated procedures are not able to determine what writing is "good" or "interesting." Computer programs can handle easily such straightforward matters as checking adherence to a specific form of expression, especially one which is as stylized as a news story.

Automated techniques can provide, for the same or less cost, analysis of more samples, more quickly, and with greater consistency than can most teaching assistants. Of course, the machine should not be considered a replacement for human response to written expression. It can serve as a useful intermediate check on mechanical factors important to a particular exercise, but the machine's interpretation can and often should be appealed to the judgment of fellow students or the teaching staff. Perhaps the computer is best viewed as an ally of the student which helps him shape his writing in the form he wishes before taking it to his peers and teachers for comment on content.

The designers of learning aids for journalism students in the schools and colleges can anticipate the performance aids these students will find in jobs and in hobbies and recreation five years later. The experience with computer processing of writing exercises obtained as students may be especially valuable to them as practicing journalists during the next decade when they encounter the methods of computer assistance in editing which are now being developed.

Objective and Method

Students need frequent and consistent reaction to their writing. However, instructors teaching composition, journalism, and technical or business reporting courses are often overburdened by large classes. The editorial analysis programs enable the journalism student to obtain from the computer a thorough and rapid analysis of both the style and content of a writing sample.

Robert Bishop, Department of Journalism, University of Michigan, initiated the editorial analysis project in July 1969 with the assistance of the Center for Research on Learning and Teaching. This note is drawn from his proposal for further development.

Expensive parsing programs used in exploration of natural language processing are not necessary. Computer procedures developed at the University of Michigan are used to examine the text of a report, essay, or article for inclusion of specific information and conformity to a particular style. The student does not need to observe any special constraints in preparation of his text; the student or a teaching assistant need only type the story on a keypunch or on-line typewriter entry station.

By using variations of the readability formulas developed by Rudolf Flesch, Robert Gunning and Irving Fang, the program computes the average length of sentences and percentage of polysyllabic words which together give an indication of the level of reading difficulty. The computer provides an overall readability rating and cites specific sentences and paragraphs which may need revision.

The editorial analysis program also points out possible violations of journalistic canons such as the overuse of articles, adjectives, cliches, or passive verbs as well as failures to conform to the Associated Press style in such matters as punctuation and spelling.

Description of Typical Use

Students in a beginning class in journalism first receive instruction in the basics of clear, effective writing. Then they are introduced to the computer-assisted writing program which will give them an opportunity to practice their writing skills.

In a typical exercise, each student is given the raw information from which to write a news story (for example the public relations release in Attachment I). The student keypunches his version of the story onto punched cards to be processed by the computer in batch mode, or, at somewhat greater expense, types his story directly into the computer at an on-line typewriter.

A computer print-out gives the student a copy of his story and the comments made about it by the editorial analysis program (Attachments 2-a and 2-b). The analysis of one exercise presently costs about $1.25 on the Michigan Terminal System (time-shared IBM 360 dual 67's). The student also receives from the instructor a "model" version of the story (Attachment 3) to compare with his own.

The student completes six exercises which require turning data supplied into articles to be checked by the computer for content as well as style. Then he is asked to write six more articles on subjects of his own choosing. He obtains feedback from the computer on each of the 12 exercises before going on to the next one.

The editorial analysis program checks each of the first six exercises on specific subjects for accuracy by comparing spelling of names and presence of specific facts to previously stored files. Completeness and order are checked by searching for key words and phrases.

All 12 articles (assigned subjects and free choice) are scanned for readability and style.

Future

Several modifications of the program would make it more responsive to the needs of the individual student. Because of the expense of computer time required, the project has not yet attempted to match a student's article against stored models. If this step were computerized, the student could receive a copy of the model story nearest his own organization and style of writing. This would permit more flexibility than comparison to the one model now handed out by the instructor.

If a cathode ray tube or other rapid display device were available, the student could edit his article on-line, enter it for processing, and then review the computer responses keyed to the original copy still shown on the screen. He could revise and retest his copy as many times as he wished to, for example, to improve its readability index.

All these techniques should lead to professional use of computers by journalists.

Attachment I

Journalism 301

ANN ARBOR, MICH. -- The University of Michigan Medical School together with the Survey Research Center is doing a study of families with chronically ill or handicapped children. Between 200 and 300 carefully selected Michigan families will be interviewed this summer by University of Michigan interviewers.

"We want to talk to parents who have been in the difficult position of having to deal with recurring illness or long term disabilities in their children. We need their help if this study is to be meaningful," said Dr. Monica Blumenthal, the principle investigator for the study.

Dr. Blumenthal and her associates are interested in the physical and mental health of parents of youngsters suffering from mental retardation, cystic fibrosis or other chronic ailments. She said there is very little information of this kind available at present.

The hope is that the U-M study, backed by a grant from the National Institutes of Mental Health, will enable the investigators to make a more definitive statement about what happens to the health picture of families when a condition of chronic illness occurs. The information would be helpful in anticipating family stress in future instances and "possibly change the attitude of some professional people handling these situations," Dr. Blumenthal said.

The families to be interviewed have been carefully selected in advance through schools, hospitals and clinics across the state. They live in virtually every major city in the State of Michigan.

Edit the story, reducing it to 150 words or less.

FAMILY HEALTH SURVEY
January 25, 1970

Attachment 2-a
Student's Version of Story

1 A study of families with chronically ill or handicapped
children is being done by the University of Michigan Medical
2 School along with the Survey Research Center. Between 200
and 300 carefully selected Michigan families will be
interviewed this summer by University researchers.

3 "We want to talk to parents who have been in the
difficult position of having to deal with recurring illness
or long term disabilities in their children," said Dr.
Monica Blumenthal, the study's director.

4 It is hoped that the University study, helped by money
from the National Institutes of Mental Health, will allow the
investigators to make a clear picture of what happens to
families when one of the members becomes chronically ill.

5 The information would assist in predicting family problems
in such cases and "possibly change the attitude of some
professional people handling these situations," Dr. Blumenthal
said.

6 The families to be interviewed have been carefully
selected through schools, hospitals and clinics across the
7 state. The live in almost every major Michigan city.

Attachment 2-b

COMPUTER ANALYSIS (Journalism 301 Story 6)

Some of your sentences appear to be too long. Check them to see if they can be condensed. If they can't, you may wish to break them into two sentences.

Check sentences 3,5.

Sentence #4 is definitely too long. If you cannot condense it, break it into two or more sentences.

Readers need to know, very early in the story, who is conducting the study. Be sure to include this detail within the first two paragraphs.

Did you check to see whether "Institutes of Mental Health" is correct?

Some words and phrases are redundant. Recheck your story. Omit any redundant phrases or words, or substitute a synonym or short phrase for long, stilted phrases.

Did you mention the Medical School and the Survey Research Center?

Your story should be shorter. Rewrite it, keeping the length to 150 words or less.

This concludes my analysis of your story. I may have missed some important elements, or may not have recognized some key phrases which you used. Correct the story according to my analysis and your own best judgment, and then compare your version with the mimeographed stories done by other students. Get these from your lab assistant.

Attachment 3 Model Version for Final Comparison

Name______________________________
Course________________Section______
Slug______________________________

What happens to a family when chronic illness strikes one of the children?

Nearly 300 Michigan families with chronically ill or handicapped children will be asked that question this summer by the University of Michigan's Medical School and Institute for Social Research.

"We want to talk to parents who have dealt with recurring illness or long term disabilities in their children," said Dr. Monica Blumenthal, the principal investigator.

The investigators hope to find what happens to the physical and mental health of families faced with a chronic illness such as mental retardation or cystic fibrosis.

The information would help anticipate family stress and "possibly change the attitude of some professional people handling these situations," Dr. Blumenthal said.

The families have been carefully selected through schools, hospitals, and clinics throughout the state. The study is financed by the National Institutes of Mental Health.

#

(141 words)

5. Execution and Test of Statistical Operations with a Real Data Base: Classroom Learning Research. (Education)

Introduction

It is assumed that sound teaching in research methods requires: (1) that the student be able to develop theories involving relationships among variables which are defined and for which suitable measures have been proposed; (2) that he be able to formulate theoretical hypotheses of a nature which would prove crucial to the theory; (3) that these theoretical hypotheses be translated into statistical hypotheses; (4) that he know the relevant research design and statistical techniques for setting up his experiment and analyzing his data; (5) that he be able to plan an experiment within valuable sets of constraints, for example, cost and time; and test his hypotheses on real data.

Objectives and Procedures

The computer program was designed to provide students in educational research meaningful hypothesis-testing experiences with a real data base. It is the task of the student to analyze copies of the tests for which scores are available, generate hypotheses as to possible relationships among the variables in the data base (see Attachment) and then, with the aid of the computer, determine whether or not the hypotheses were supported.

The programs are not designed to instruct the student in statistical computation procedures, but to provide the statistical results for the hypotheses the student wants to test. This allows the student to function as an inquiring researcher.

A quiz is given to each user testing his knowledge of the statistics he chooses to use. The computer will calculate only those statistics for which the user has passed. (At the present time the program is written to calculate

---

This computer program has been developed in the past two years by Uldis Smidehens, at Western Michigan University, David D. Starks and Wayne Davis both at Center for Research on Learning and Teaching at the University of Michigan. Programming assistance was provided by Ilona Cohen, Steve Marston, and John Bauer. The work was supported in part by a grant from the Air Force Office of Scientific Research (AFOSR-68-1601).

means, medians, modes, standard deviations, correlation coefficients, and t-tests.) The student may select a sample (random, stratified, or entire population), select the size of the sample if it is random, and determine the statistic the computer is to calculate.

The students test their hypotheses on a real data base. Therefore, the hypotheses they test are potentially meaningful and the relationships they discover exist within the sample that was tested.

Description of Typical Use

First the instructor discusses the data source and its original use, and features of the program which will help the student test his own hypotheses. A portable computer terminal is brought into the classroom and operated by an assistant, making an easier introduction for students who have had no previous experience giving instructions to a computer. The students formulate hypotheses based on information given them about the original data file and psychological tests used, and learn immediately which of these may be supported by the data.

The students then sign up to use the program in groups of three to pursue more careful definition and testing of hypotheses. The use of groups stimulates discussion which results in the generation of more interesting hypotheses than constructed by most individuals, and having a second student present helps each individual learner confirm his progress.

The computer cost per group per hour was approximately $2.50, about 60¢ per student.

Most students easily mastered the program. After a warm up period in which the main concern was finding the correct keys on the keyboard, many good questions were asked. The most interesting questions were usually generated from the results of the calculations they had planned to do when they entered the terminal room. Often their original hypothesis was not supported, and they tried to find out why by looking at different variables or different samples.

Suggestions for Future Use

This system is significant because it gives students an opportunity to do something that has been difficult to do before in a class in research design, i.e., work with real data. Even more important it leads students to use the computer for work in other courses or for independent study.

Attachment I

The data available for analysis were collected in a longitudinal study of creativity, achievement, ability, and certain personality factors by Denny, Starks, and Feldhusen. The data were obtained in 1962 for 239 children in seventh and eighth grades in a small city school system on the following: the Consequences Test (Christensen, Merrifield, and Guilford, 1969) which yields measures of ideational fluency and originality, the Alternate Uses Test (Christensen, Guilford, Merrifield, and Wilson, 1969) which yields a measure of spontaneous verbal flexibility, a creative traits checklist, SCAT, STEP, and anxiety (Sarason, et. al., Gen anx. 1969.) Followup data were obtained in 1966, when the students were in eleventh and twelfth grades, on the following: the same divergent thinking tests, the same checklist of creative ability. The peer nominations were obtained by having all students identify the five most creative boys and the five most creative girls in their class (11th and 12th grades). The score is the total number of times a student was nominated by his peers. A separate set of scores was generated when these scores were converted to a six-point normalized scale to correct for abnormality of the distribution.

The teacher nominations were secured by having all teachers identify 5 to 20 each of junior and senior boys and girls. Scores were reported for teacher ratings in the same way peer ratings were reported.

The checklist of creative traits yielded seven scores:

(1) Factor I, derived from a factor analysis, socially conforming creative self view.
(2) Factor II, socially non-conforming creative self view.
(3) Factor III, energetic and dynamic creative self view.
(4) Factor IV, diffident and/or withdrawing creative self view.
(5) Total number of items checked on the checklist.
(6) Score on items which are correlated with an objective measure of ideational fluency.
(7) Score on items which are correlated with an objective measure of flexibility.
(8) Selected items with high correlation with total score.

A sample of 192 students was used (116 boys and 76 girls for whom complete 1962 and 1966 data were available

Attachment II

Name ______________________

Date ______________________

I. State the question you wish to ask:

II. State the method you will use to answer your question:

A. Sample to be used

1. entire population
2. random group N= __________
3. stratified group Stratified on ______________

B. Calculation to be used

1. mean
2. median
3. mode
4. standard deviation
5. correlation
6. t-test

III. State the results of your investigation

IV. What conclusions have you reached regarding your question?

Attachment III

This attachment consists of two sample interactions between a student and the computer. In the first the students intended to determine if teachers, when asked to rate the most creative students in their class, probably rate something more like IQ. They hypothesized that there would be a high positive correlation between a student's IQ and the number of times he was selected by his teachers as being creative. As a result of the initial correlation coefficient of .58 (using a random sample of 45), they wondered if a student's peers rate him in a manner similar to the teacher. They produced a second correlation with the same sample, obtaining this time a coefficient of .41. It is now the responsibility of the students to interpret the results of his investigation.

The second interaction shows students testing a difference between IQ scores for boys and girls in the total population available. The two samples (boys and girls) were selected and a t-test was performed to test for a significant difference. Again the students must interpret the results; further confirmation and new ideas are obtained from class discussion.

Attachment IV

```
SOU STATISTICS

#$SET ECHO=OFF
#EXECUTION BEGINS

STATE AN HYPOTHESIS

GIRL'S IQ SCORES DIFFER SIGNIFICANTLY FROM BOY'S IQ SCORES


SELECT A SAMPLE (SLIDE 1)

STRATIFIED

SPECIFY YOUR FIRST  SUBGROUP


SEX

MALES OR FEMALES?

FEMALES

FURTHER STRATIFICATION?

NO

N=  76      (TOTAL NUMBER OF GIRLS)


ENTER THE NAME AND GRADE-LEVEL OF A TEST

IQ SENIOR

SELECT A CALCULATION (SLIDE 2)

T TEST

WHICH HYPOTHESIS DO YOU WISH TO TEST?

     1) MEAN = CONSTANT

     2) MEANS OF TWO SAMPLES ARE EQUAL.

2(MEANS OF TWO SAMPLES ARE EQUAL)
```

Attachment IV

```
FOR THE SECOND TIME (THIS TEST)...

SELECT A SAMPLE (SLIDE 1)
                                      → (STUDENT MUST NOW SPECIFY
                                      → THE GROUP WITH WHOM THE
STRATIFIED                            → GIRL'S IQ SCORES WILL BE
                                      → COMPARED)
SPECIFY YOUR FIRST  SUBGROUP


SEX

MALES OR FEMALES?


MALES

FURTHER STRATIFICATION?


NO

N= 116        .(TOTAL NUMBER OF BOYS)


ENTER THE NAME AND GRADE-LEVEL OF A TEST


IQ SENIOR

WHAT ASSUMPTION DO YOU WISH TO MAKE

ON THE VARIANCES OF THE TWO SAMPLES?

     1) THEY ARE EQUAL
     2) THEY ARE NOT EQUAL
     3) NO ASSUMPTION (BOTH VALUES OF N MUST BE EQUAL)


1    (EQUAL VARIANCES)

T=      -1.22 WITH 190 DEGREES OF FREEDOM.

                                    → (STUDENT MUST NOW USE TABLE
                                    → TO DETERMINE IF 1.22 IS SIGNIF.)
WHAT DO YOU WANT TO DO NOW? (SLIDE 3)


STOP

THANK YOU.
```

VOLUME I - APPENDIX D

DOMAIN OF COMPUTER USE DEFINED FOR PROJECT CLUE

CONTENTS

A Problem of Names 3

(The origins and connotations of various acronyms are compared; Project CLUE staff have avoided use of any simple labels for the entire field of instructional use of computers.)

Modes of Computer Use 5

(The usual approach to characterizing the variety of uses of computers in the instructional process is described; classifications of ten writers are compared in a summary table; modes are grouped into four areas.)

Instruction and the learning process
Management of instruction resources and process
Preparation and display of materials
Other uses of information processing

Dimensions of Use 9

(An alternative approach to describing computer use intended to emphasize the computer contribution to learning and performance and the user's perception of the machine aid; six tentative dimensions.)

Program control
Diagnosis and prescription
Type of interaction
Variety of functions available to users
Role of the computer for the individual serviced
"Naturalness" of the communication between learner and system

Summary of Trends 14

(The proposed dimensions for analysis of computer uses are suggestive of some directions which current development work appears to be following.)

Address comments to: Karl L. Zinn, Director
Project CLUE
1315 Hill Street
Ann Arbor, Michigan 48104

Project CLUE

December 1970

Project CLUE has considered uses of the computer and information processing sciences to assist with instruction and learning in education and with the development of learning materials and related information resources.

The broad context of discussion should be (automatic) information processing systems in education; some of the more specific references are computer-assisted instruction, computer-assisted instruction management, information storage and retrieval, computer-generated instructional materials, and discipline-relevant aids to skills practice and scholarly work by learners.

Administrative uses of the computer for record keeping, scheduling, resource allocation, and data processing were not included in survey and review activities and are mentioned only incidentally. Although these administrative uses are extremely important to educators, critical review of this area was not as urgent as for the instructional domain, and particularly for the "conversational tutorial" uses which are the subject of some controversy.

Interactive uses of the computer with the user station directly connected ("on-line") are often quite costly to implement at their present stage of development, and occasionally the same function can be served just as effectively and less expensively without the direct connection ("off-line"). The scope of Project CLUE includes all uses of the computer for instruction, whether the student waits one second or 24 hours for a reply to his action. Some systems are arranged to provide results in from one to 30 minutes from a "remote job entry" terminal. The user does not have to carry his punched cards to the computer center but is able to interact with the machine using a card reader and printer located for his convenience.

A Problem of Names

The uses of the computer as an instructional aid have been represented by a number of acronyms including CAI, CBI, CMI, CAL, CAE, and many others. Some persons associate these labels with particular uses of computers, university projects, or computer manufacturers. As a result any single acronym can mean different things to different readers.

"Computer-assisted" or "computer-aided instruction" (CAI), used by IBM research staff in early writing about instructional systems, is now the most commonly used acronym. System Development Corporation began with the label "computer-based instruction" (CBI), which was later adopted by Stanford University and RCA. "Computer-assisted learning" and "computer-augmented learning," it has been suggested, are more descriptive of the variety of uses of the computer in education. However, the resulting acronym (CAL) would be confused with that adopted for two different computer languages.

If the computer's role is to assist the teacher in managing instruction by handling performance records and curriculum files, the label used is "computer-managed instruction" (CMI). In this use, the student does not receive instruction directly from the computer, but only information about non-computer media which are prescribed for him on the basis of test scores and other information the computer may have about his current performance and background. When the information is given to the teacher for interpretation and final decision before lesson materials are suggested to the student, a better label is "computer-assisted instruction management" (CAIM).

Staff at Stanford Research Institute coined the phrase "augmentation of human intelligence" (AHI) for innovative work in computer-based systems which aid the user in various tasks including education. A few instruction-oriented projects have picked up that label to emphasize that the computer is to be viewed as an aid to and an extension of the intellectual abilities of the learner rather than as a drillmaster or mentor supplanting his self-discipline, motivation or integrity. AHI is not widely used as an acronym in the area of instructional use of computers,but the connotation seems to be increasing in favor.

Because acronyms tend to become associated with one manufacturer, computer system, or research and development project, they do not adequately label the entire field. For some observers the CAI label implies author control to the exclusion of the many possibilities for student initiative and direction of the computer processing during instructional activities.

Authors of Project CLUE interpretations have avoided use of acronyms and when the CAI label appears in these documents it refers to a narrow definition of computer use, e.g., drill and tutorial activity. More comprehensive phrases are intended to indicate the wide scope of computer uses for instruction, for example, "computer-based learning exercises" or the "computer as a learning tool," or simply "computer uses in instruction." These phrases emphasize the learning process as much as a highly controlled instruction process and the extension of the intellectual capabilities of the user as much as the testing of his factual knowledge. Nevertheless, adoption of any acronym such as CBLE or CLT or CUE has been avoided since it would only add to the confusion of initials and meanings.

Modes of Computer Use

Many writers have prepared schemes for classification of modes for computer use. To help a reader new to this area organize his thinking and handle the different sets of terms used in various publications, Project CLUE staff have prepared a list of modes which seems to encompass the others; it is not intended as another competing list of modes or as a standard. Existing

Other uses of information processing. A number of other potentially interesting categories are listed but without elaboration since they are not central to this discussion. Nevertheless, computer users give considerable attention to the educational implications of computers in administration (accounting, scheduling, planning, etc.), research (institutional, sociological, psychological, instructional, etc.), and to the relation of instruction to various applied uses. The last area is especially important because of needs for pre-service training in science, technology, management, banking, production, retailing, etc.

This conception of the variety of modes of computer use, arranged to incorporate the classification schemes by other authors, may be useful only to promote awareness of terms which already appear in the writing of this field. In fact, it may distract from the primary purpose of serving learners and, secondarily, institutions.

Analysis and recommendation regarding computer use require some consideration of the dimensions which might underlie these various schemes for classification and the actual opportunities and constraints of computer use by learners. A tentative set of dimensions is given in the next section.

Dimensions Underlying Modes of Use

The criteria to be used for classification according to the various schemes put forth in published writing have not been clearly expressed. This is not surprising since in most cases these classifications are used only as illustrations of what might be done. It should be much more interesting to determine the underlying assumptions from which categories have been derived. Some set of essential dimensions should prove to be more helpful than the total of the classification schemes.

Project CLUE staff have tried to identify several dimensions of use and their relations to each other. The tentative conception given here is not exhaustive or theoretically comprehensive.

Program Control. Computer-based lessons differ in the control the writer has over the student's course of study. At one extreme the student can only follow the program; typically he finds himself more restricted working at a computer terminal than he would be with a textbook or set of drill exercises. That is, the writer of a tutorial exercise has not provided the computer instructions which would permit the student to look back, review or skip ahead as he does with printed materials.

Control is desirable in some situations, and curriculum designers have used this facility of the computer to reduce inappropriate skipping about or other distractions. Control is also an advantage when the lesson designer is testing his materials and wishes to know exactly what each trial student has seen and when.

At the other extreme, characterized by almost complete user control, the computer is programmed to serve the student as a tool in the management of the information necessary for solving a problem or achieving some other goal. The most common use is as a conversational computer; that is, for calculations and other immediate processing in response to directions from the student. A lesson designer can also give the student access to large files of information so he can retrieve and rearrange facts as he finds them useful in his study.

Diagnosis and prescription. Another dimension of computer use concerns the extent of data recording and interpretation in the interactive program structure, e.g., the program's facility in diagnosing difficulties and prescribing new tasks on the basis of student performance and attitude. At one extreme the computer follows student instructions for problem solving or presents simple linear programs for practice exercises without paying any attention to the student's problem solutions or to his response to questions. At this "zero level" there is no interpretation or prescriptive feedback determined by the author's procedure to be displayed to the student or saved for the future use by the program procedure itself.

In typical tutorial uses the computer program processes student responses and tries to act upon them during the instruction sequence by selecting for the student appropriate remedial or new materials. Such a program could also give interpretation of response measures directly to the student, e.g., telling him why he needs more practice with or without allowing him control over future action.

Problem solving environments, typically unconstrained, may also include interpretation of student actions, e.g., presentation of the correct form for an ambiguous instruction, suggestion of a solution procedure along a direction already taken by the student, and evaluation of his final solution for efficiency in terms of number of instructions or computer time used.

For any level of diagnosis and prescription, the extent of control over the direction of instruction may vary from nearly zero (where the student has almost complete control) to maximum control by the computer program. In other words, the program may tell the student why or on what basis he is being led through an exercise, whether or not he is permitted to change it. Similarly, any level of control allows the full range of prescription. However, if the computer is to have a justifiable role when programmed to maintain maximum control, it must be acquiring and interpreting information for use in the controlling procedure. Although the author may wish to have the computer record and store the maximum of relevant information justified by potential use in guiding students, he must design a procedure for diagnosis and prescription which passes along to each student only as much as promotes learning and favorable attitude, and avoids the distractions of too much information or irrelevant items.

Variety of functions available to users. The scope of opportunities for a user (whether student or author) in an instructional system varies from the limited possibilities of a completely pre-programmed exercise to the full capabilities of a richly-equipped and general-purpose system. The systems dedicated to "drill and practice" are examples of a limited variety of functions available to the user: authors assemble pairs of items for presentation according to a preset strategy of "show the question item for a time, then show its corresponding answer," and students work on the exercises in sequence and within the interactive capabilities of the system. Perhaps authors may be allowed to adjust criteria for triggering a standardized computer response of "wrong, try again" or "too long, try again," and students may choose among two styles or drill exercise.

Actually a drill-oriented system may allow for considerable "variety" in the sense of programming capabilities or functions believed to be worthwhile for the instructional use of a system. A package of drill exercises may include alternative ways to achieve the same performance goals, and the author may write a complicated procedure to select among them on an individual basis using observed student learning characteristics and current performance.

Although drills of limited purpose measure high on "program control," they can also measure high on the dimensions of variety and prescription. Variety is an obvious dimension to be considered in deciding upon the content to be utilized in a dialogue, the programming languages available for solving a problem, the alternative models to be used as a basis for a simulation, or alternative techniques available to the student to reprogram the model underlying the simulation.

Type of interaction. As a dimension underlying computer use, "interaction" refers to a computer operation in which particular attention is given to the continuing exchange between user and program. Typically the user types some instructions, the computer types back partial results, the user modifies his original statement or continues with new instruction, and the computer responds again, etc. "Interaction" refers not only to the speed or rate of exchange between user and machine but also to the extent of dependency of computer reply on user input and vice versa.

"Interactive" has been used as a label for certain types of programming languages and problem-oriented systems which have special features to facilitate "conversation" between user and machine. The lesson (or system) designer knows the student (or other user) will be there to answer questions when the procedure can not initiate useful action, and that the user will interrupt the procedure when it begins typing out more than is necessary. Thus the designer will automate only parts of the process and leave the remainder to the judgment and initiative of the learner.

Interaction may also imply "dynamics," e.g., changes in parameters and substance to "generate" new content or rules or procedures for the student presently being aided, but in a fashion not anticipated in detail by the lesson designer. If full prescription could have been given in advance, delivery could have been made without a generalized information processing device, i.e., with some less expensive device such as a slide projector or book!

Role of the computer for the individual serviced. The student may see the computer program as a device which does scoring, analyzing, or retrieving for him; in general, those things he would rather not do himself. Or he may see it as a test imposed on him or an exercise he must complete. If the student does see the computer as a servant doing his bidding, and a study aid doing what he asks, he may give the results of processing more attention and thereby better use the device to further his learning objectives.

The teacher, on the other hand, may see the computer system as a proctor of required exercises and a validator of performance in testing situations. Of course, the individual students still must be proctored by some teacher or student aide if the system is to protect against one student sitting in for another, or using inappropriate aids of whatever kind (books, notes, another computer, etc.). Someday machines may automatically check fingerprints or "voiceprints," and various written and procedural aids will be assumed available as part of the performance task.

Human attitudes toward the machine cannot be as predictable or as easy to determine as perhaps the degree of program control or amount of diagnosis and prescription. The role of the computer will be viewed from as many different perspectives as there are people using it, and the user's view of the computer will interact in varying degrees with other dimensions.

"Naturalness" of the communication between learner and system. At one end of a dimension of natural to formal (or pre-coded) language, the computer is programmed so that the student may respond with terms and conventions natural to him, and little if anything about system operation need be learned to use it. For language-oriented topics the computer program must be capable of performing complicated textual analysis in order to conduct a dialogue with the student. The computer's ability to process natural language, and subsequently to diagnose and prescribe on the basis of statements made by the student without any constraints, approaches the realm of "artificial intelligence" and presently is very much in a theoretical and experimental stage of development.

At the other extreme the user must learn how to give messages to the system, to recognize what has been interpreted successfully, and when to call on human aid if the system does not respond understandably. Learning computer conventions is no hardship for topics of study in which the conventions of computer use are consistent with the objectives of instruction. Formality of communication is desirable in the sciences and engineering where the computer and its programming conventions provide appropriate constraints on theorizing and model building.

Summary of Trends

These six dimensions can be viewed as defining a space or domain of computer use, and the modes usually mentioned as simple categories (drill, tutorial, dialogue, socratic, simulation, learner-directed, etc.) are more appropriately described as filling some part of this domain. This conceptualization has been used by Project CLUE in a tentative way to establish among users a broader perspective on computer use, and to open up new possibilities for computer service to learners.

A major trend in design of computer-based exercises is a shift from program to learner control. The designer of the exercise is putting less energy into a careful diagnosis and prescription accomplished by some automated instructional strategy and more effort into providng information from which the student can derive his own diagnosis and into making available alternative interpretations and guidance from which the student can assemble his specific prescriptions.

Most systems and lesson designers are providing an increasing variety of functions for the user of the learning system. More attention is being given to interaction, not simply how quickly a reply can be made to some question, but the actual responsiveness of the system to the particular input. This means that machine responses are increasingly dependent upon the commands and questions and answers typed by the student, and the lessons are designed in a way that the student is more likely to respond to information provided by the computer.

A very important trend concerns the role of the machine from the perspective of the individual using it. The teacher is now more likely to see computer-managed instruction as an aid to human management than as a replacement for it. Probably much more important, learners find the machine more suitable as an aid to learning than as a drill master.

Naturalness of communication between learner and system is being improved day by day. Computer-based learning exercises are achieving increased relevance for the subject being studied, and the nomenclature and conventions that have to be learned to use the system tend to be essential to the study of the topics (apart from the requirements of the computer as a medium of presentation).

VOLUME I - APPENDIX E

GLOSSARY FOR COMPUTER USES IN EDUCATION

This glossary is for the novice reader. Jargon has been avoided to the extent possible. Some definitions may be technically incomplete but hopefully none are erroneous or misleading.

Terms are defined from an educational orientation; the same words are used throughout the information sciences, occasionally with other connotations. Most of the definitions include a sentence using the word or phrase to clarify the meaning. These sentences sometimes express opinion rather than fact.

Longer glossaries with complete technical definitions are available. Two rather official ones are listed below. Although not concerned exclusively with educational uses of computers, they provide standard definitions of many terms used in computing and information processing.

> USA Standard Vocabulary for Information Processing. New York: American Standards Association Institute, 1966.
>
> Automatic Data Processing Glossary. Bureau of the Budget. Washington, D. C.: Government Printing Office, 1964. PREX2.2:AU8/2.

Shorter glossaries, often with simplified definitions, are available from most computer manufacturers and some professional societies.

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access time Time required for the central processor of a computer to obtain information from a storage device (read-time), or to put information away in storage (write-time). An educational computer system serving many users simultaneously needs a storage device with short access time from which to recall frequently used information.

acoustic coupler A device used to connect a user terminal to an ordinary telephone for the purpose of transferring information over telephone lines via an audible signal to the computer. A "data set" (modem) is wired directly between telephone and terminal device, instead of coupled by sound with a microphone and speaker; it is not affected by room noise but is more expensive than most acoustic couplers.

AHI (Augmentation of Human Intellect) Computer techniques for retrieving, re-arranging and manipulating information, usually text, sometimes diagrams, or anything that helps one engage in intellectual activity; computer extension of human abilities to accomplish instructional research, compositions or other creative work. AHI is the name of a research and development program at Stanford Research Institute.

algorithm An unambiguous, step-by-step terminating procedure for solving a problem. When properly applied, an algorithm always produces a solution to the problem. (Contrast with "heuristic.")

analogue computer (also, analog) A device which uses voltages, forces, fluid volume or other continuously variable physical quantities to represent numbers in calculations. It is convenient for solving differential equations, simultaneous equations and equilibrium problems. (Contrast with "digital computer.")

ASCII (American Standard Code for Information Interchange, often pronounced as'kee) Established by the American Standards Association as the standard for representation of numbers in computing machinery and communications. All user terminals today should use ASCII code.

author-controlled tutorial mode (See "tutorial mode.")

bandwidth The difference, expressed in cycles per second, between the highest and lowest frequencies of a band or part of a channel; a determinant of amount and quality of information which can be passed per second. Bandwidth is measured in cycles or bits per second (cps or bps), kilocycles per second (KC) or megacycles per second (MC). Preferred notation in information science is Hertz (KHz and MHz). A low bandwidth telephone line will not carry information fast enough for rapid display of complicated graphics at a remote site.

batch processing A term applied to one method of collecting and processing several jobs on a single computer. Separate and self-contained jobs are collected in "batches," then processed to completion, usually in the order submitted. Most computing systems accomplish more processing per hour when the jobs are submitted in batches. (Contrast with "multiprocessing" and see "time-sharing.")

baud Bits per second; a measure of transmission rate. A 110 baud channel typically carries 10 characters per second or about 60 words per minute.

binary device Any physical device having two states: on-off, yes-no, true-false. Most computers are made up of many elementary binary devices. (See "core.")

bit (contraction of "binary digit") A unit of information content; the smallest element of binary computer memory or logic. (See "core," "binary device," and "byte.")

branching Altering the sequence followed within a set of instructions (a computer program) by switching when some predesignated event occurs. Branching provides a change in instructional procedure as a result of an individual learner's performance.

buffer A storage device used to compensate for a difference in rate of flow of data, or time of occurrence of events, when transmitting data from one device to another. The slow typing by a user may be collected in the buffer of his terminal device and then sent (on command) at a much faster rate to the central computer for processing.

byte A group of bits (usually six to eight) representing a character; for some computers, a byte is the smallest addressable unit of memory.

CAE (Computer-assisted education or computer-augmented education) CAE implies a broader range of computer uses than CAI.

CAI (Computer-assisted instruction, computer-aided instruction, or computer-augmented instruction) Defined narrowly, it refers to tutorial exercises or computerized programmed instruction; defined broadly, it encompasses the entire field of computer uses for instruction in which there is an interaction between student and machine (e.g., drill, tutorial, simulation, problem solving, and scholarly aids). (Contrast with "CMI;" see also recommendations and Appendix D on discussion of domain in Project CLUE.)

CAIM (Computer-assisted instruction management) Same as "CMI" with emphasis on assistance to human manager of instruction rather than direct management by computer.

CAL (Computer-assisted learning) Similar to CAI and CAE but with connotation of greater attention to or service for individual learners. Also the name of an on-line computation language developed at the University of California at Berkeley and a coursewriting language developed at the University of California at Irvine.

CBI (Computer-based instruction) Similar to CAI and CAL but this acronym is used less frequently.

CBL (Computer-based learning) Connotation of greater attention to or service for individual learners; less frequently used than "CBI."

channel A path for electrical transmission between two or more points. Also called a circuit, line, link or path.

character A digit, letter or other symbol, usually requiring six to eight bits for representation in digital computers.

CMI (Computer-managed instruction) Computer aids for which the main function of the computer is to assist in planning instructional sequences. The actual instructional activities suggested through CMI may or may not involve the computer. (Contrast with "CAI.")

compiler Computer program for translation of instructions expressed in a particular user language (e.g., FORTRAN, ALGOL) into a machine language (i.e., binary numbers signifying basic operations such as add, compare, store and jump) for repeated execution. (See "translator" and "interpreter.")

computation mode Calculation, information retrieval and text processing as aids to study and performance; in a sense this mode of student use provides "direct access" to knowledge and procedures for handling knowledge.

connect-time Elapsed time of use, from time of connecting with the computer to time of disconnecting. Some commercial time-sharing services charge only for connect-time regardless of computing resources (e.g., central processor time and storage) actually used. (Contrast with "execution time.")

core The rapid-access memory of a central processing unit; usually made of many small rings (cores) of magnetic material which may be in either of two states of polarization. Frequently used information usually is kept in core during execution of a program in order to save the delay and cost of obtaining it repeatedly from a slower speed memory device.

course Used rather loosely within CAI projects to mean any instructional sequence or computer-based learning exercise. Many CAI systems have only a few demonstration courses operating successfully.

CPU (Central Processing Unit) The central section of a computer including the control and arithmetic units

CRT (Cathode Ray Tube) A television-like device for electronic display of drawings and text. The CRT is a popular device to include in a user station because of speed and (sometimes) drawing capability. Other devices can serve the same function. (See also "plasma panel.")

cursor A point or line of light displayed on the cathode ray tube and under the control of either the user or the computer to indicate the point at which the next display or editing operation is to occur. The cursor is one means of providing the user with a capability to point (See also "light pen" and "RAND tablet.")

data cell A device which stores and retrieves blocks of information on strips of magnetic tape by automatically transporting these strips from a storage cell to a reader and back. A data cell operates more slowly than disk storage, but is less expensive per bit and has a larger capacity. (See also "diskpack" and "tape.")

data-phone A trade mark for the data-sets manufactured and supplied by the Bell System; a service mark for the transmission of data over the regular telephone network (DATA-PHONE Service).

data-set A device for transmission of data over the regular telephone network. An "acoustic coupler" does not have to be wired into a telephone system; that is, it "connects" by sound to any telephone handset, but it is more affected by room noise than the direct-wired data set. Also called modem.

debug To search for and correct errors ("bugs") in a computer program. Debugging is often very costly and time-consuming in complicated programs.

diagnosis and prescription As a dimension of computer use, the extent of data recording and interpretation in the interactive program structure, for example, the program's facility to diagnose difficulties and prescribe new tasks on the basis of student performance and attitude.

diagnosis and testing mode Computer use in which the student is tested on his understanding or performance and he or his teacher is given some interpretation of results. In some diagnostic testing a computer procedure is employed which minimizes the testing time required to obtain enough information for a reliable decision about the performance of the examinee.

dialogue tutorial mode Tutorial use in which student assumes greater control over the selection and sequencing of messages which make up the conversation. The lesson designer must establish files and search algorithms that anticipate and respond usefully to student questions.

dial-up service Ordinary access via telephone to other telephone instruments and the computer that may be connected to them. Dial-up service is paid for by recorded minutes of use. (Contrast with "tie line.")

digital computer A device which uses digits to express numbers and special symbols in calculations and other information processing. A digital computer is the most common type of automatic data processor. (Contrast with "analog computer.")

diskpack (also disc) A stack of disk-like plates coated with magnetic material for the storage of information; bits can be stored upon and read from the surface while the pack revolves at high speeds, somewhat like a stack of phonograph records combined with the record-playback capability of a tape recorder. (See also "drum" and "data cell.")

display and composition mode Computer use in which a composition is constructed, perhaps a graphic display in art or engineering, or text for a newspaper story or the like in a writing course. A mode of display and composition, typically is expensive and depends heavily on specially written procedures for convenience in constructing graphic displays or processing language text.

documentation Description of a procedure or computer program, both the internal process and the manner of use. Accurate and appropriate program documentation often determines whether that program will be used by others.

down-time Time during which a computer is not available for operation, usually because of a failure in the equipment. Down-time of one hour per day, especially when it comes unexpectedly, is not tolerable for serious educational uses of a computer system.

drill mode Computer use in which the student receives straightforward exercises; typically each question has only one or a few correct answers. The drill mode usually depends on a file of test items which are presented according to some preestablished sequence, drawn at random for presentation, or possibly generated from stylized forms.

drill-and-practice-mode See "drill mode" and "practice mode."

drum A cylindrical drum coated with magnetic material for the storage of information. Bits can be stored upon and read from surface while it revolves at high speeds. The rate of data transfer from a drum to CPU (central processing unit) is ordinarily more rapid than a similar transfer from disc or tape to the CPU.

duplex In communications, refers to simultaneous independent transmission in both directions (sometimes referred to as "full duplex"). In duplex operation the user is able to send new instructions to the computer at the same time his terminal device is printing the results from the last request. (Contrast with "half-duplex.")

execution time Time during which the computer is actively processing a user's job; roughly equivalent to "connect-time" for strictly batch processing, but not for multiprocessing (When the computer is executing more than one job at a time). Execution time is a major determinant of charges on some time-sharing services.

exposition mode See "tutorial mode."

facsimile (FAX) Transmission of pictures, maps, diagrams, etc., by electronic means. The image is scanned, transmitted by telephone or radio, reconstructed at the receiving station, and duplicated on some form of paper.

feedback In programmed instruction, feedback is information supplied to the student regarding the appropriateness or correctness of his last statement or response. Feedback usually is designed to confirm a correct answer or to improve an erroneous one.

flag An indicator of some condition recognized by a computer procedure; sometimes recorded only by setting one bit or switch in computer memory. Typically a flag is printed out for the user in connection with the step at which the condition was recognized, e.g., an AMBIG printed after a program statement which was found by the computer processor to be ambiguous.

flow diagram (flow chart) A schematic or block representation of programming strategy. An instructional strategy or branching procedure often can be presented schematically by a flow diagram.

frame The smallest unit of programmed instruction. A CAI frame usually consists of information and/or a question, an opportunity for an answer, and some provision for checking the answer.

generative techniques Standard patterns, procedures or algorithms applied to curriculum files for the generation or assembly of sequences of instructional materials. Generative techniques provide one alternative to programming tutorial materials frame-by-frame and word-by-word.

half-duplex In communications, refers to an alternate, one-way-at-a-time, independent transmission (sometimes referred to as "single"). (Contrast with "duplex.")

hardware The equipment components of a computer system; the machinery as opposed to the programs which are run on the machinery. (See "software.")

heuristic An intuitive guide to finding a solution to a problem; a problem-solving strategy. (Contrast with "algorithm.")

individualized instruction Adaptation of instructional methods and materials to a learner's individual characteristics and background.

information storage, organization, and retrieval mode (ISOR) Use of the computer to store, retrieve and assist in the reorganization of information about a subject. ISOR (or ISR or IR) is an established area within computer science.

instructional programming language A computer language or notation particularly suited to the description of instructional procedures for computer delivery. (See "programming.")

instructional use of computers Uses of the computer and information processing sciences to assist with instruction and learning in education, and with the development of learning materials and related information resources.

interactive mode Computer use in which particular attention is given to the continuing exchange between user and program (or system). Typically the user types an instruction, the computer types back (or otherwise provides) partial results, the user modifies his original statement or continues with new instructions, and the computer responds again. An interactive drill program checks the time and accuracy of answers and responds immediately to the user; an interactive problem solving system responds to solution attempts by the user and allows modification in the procedure at the moment. (For non-interactive, see "batch processing.")

interface A shared boundary, for example, the boundary between two subsystems or two devices. A specially-wired box may provide the interface between a terminal and a computer; the terminal is considered the interface between the user and the computer system.

interpreter A program for user-language translation (e.g., BASIC to machine language). An interpreter is roughly equivalent to a "compiler," except that each statement is executed right after translation, providing the user with a rapid response to small steps and a dynamic working environment. (See "translator.")

interrupt A hardware feature which allows the signalling of asynchronous, possibly unplanned, events within a computer. Usually the computer is able to stop its current task, process the interrupt task, and return to the original task without loss of results. Interrupts are used by asynchronous devices to indicate their current status and by CPU's to indicate the occurence of error conditions. The interrupt is a hardware feature; the processing of interrupts is performed by programs known as "interrupt routines".

INWATS Similar to WATS but allows inward calls at a flat monthly rate. INWATS provides a kind of automatic, collect station call.

I/O Input-output of information to and from computers. I/O usually refers to devices such as an electric typewriter, card reader and punch, paper tape reader and punch, printer, etc.

IPI (Individually Prescribed Instruction) An approach to curriculum which originated with an instructional project at the University of Pittsburgh's Learning Research and Development Center; now used widely as a label for a strategy of individualizing the selection of exercises and the rate of work for each student.

job An independent set of instructions and data submitted to a computer for processing; the computing done between entry onto the computer and exit from it.

joy stick An electromechanical device for indicating position to a computer, for example, to move a cursor about on a CRT (cathode ray tube). It may look like an airplane control stick and function in a similar way. (See also "light-pen," "mouse" and "RAND Tablet.")

K Thousand; e.g., 32K words of memory means 32,768 words of computer memory. K means 1,024 or (2^{10}) when applied to computer memory since it is usually constructed in units handling a capacity measured by a power of two.

learner control mode The designer of an exercise can provide the user with almost complete control, programming the computer to serve him as a tool in the management of information and procedures useful for solving a problem or achieving some other goal, relying on user initiative.

LDX (Long Distance Xerography). A name used by the Xerox Corporation to identify its high speed facsimile system. The system uses Xerox terminal equipment and a wide band data communication channel. (See facsimile.")

latency (student response time). The time from the display of an instructional stimulus to the start (or completion) of the student's response. Latency is used as a measure of student performance, especially in research studies.

light-pen A photo-sensitive device used for communication with a computer via a cathode ray tube; an electronic pointer. The light-pen is admired greatly by some users, but other means of pointing and drawing electronically often are more practical. (See also "RAND Tablet," "joy stick," and mouse.")

linear programming a) Mathematical: techniques for optimizing a linear function of several variables subject to linear inequality constraints on some or all of the variables; b) Instructional: the simplest form of programmed instruction or CAI; all students follow the same sequence.

line switching The switching technique of temporarily connecting two lines so that the stations directly exchange information. Ordinary telephone connections through dial-up service are achieved by line-switching.

link See "channel."

log To record student-computer interactions and/or performance data; a record of student-computer interaction.

memory The storage components of a computer with which bits of information are stored and from which they may later be recalled. (See also "storage.")

microwave All electromagnetic waves in the radio frequency spectrum above 890 megacycles per second. Microwave facilities provide an economic means of wide bandwidth transmission when the installation of transmitting relay towers is justified by continuing use near full capacity.

mode (of computer use) Manner of use from the student's perspective: drill, testing, exposition, practice, problem solving, model building, etc. A classification of modes is not necessary; in fact, it may distract from the primary purpose of serving learners and, secondarily, institutions. (See also recommendations and Appendix D on domain of discussion in Project CLUE.)

model An idealized representation that demonstrates the relationships between relevant variables. Models are used to better understand and control a real situation; computers make the study of models more accessible to students without sophistication in mathematics.

model construction mode Computer use in which the learner designs, specifies, and examines the behavior of models represented by computer procedures. A student working in the model construction mode already has some experience with the discipline, its theory and models, as well as knowledge of a suitable model definition language. (See also "simulation.")

modem Modulator-demodulator; a device which couples the user terminal (or central computer) to a telephone line by converting electrical pulses to audio signals (for telephone transmission) and back again.

mouse A device for determining the location of a cursor on a display screen (CRT). A mouse-like box is moved about on a horizontal surface under the user's hand, causing a cursor (pointer) to move up in a corresponding way on the screen. (See also "joy stick," "RAND Tablet," and "light-pen.")

multiplexing Using a single transmission facility divided into two or more subchannels. A school may rent a single phone line to the site of a remote computer and serve 16 user terminals simultaneously by multiplexing.

multiprocessing A method of operation in which components of a computer facility are shared by several users for different purposes at (apparently) the same time. Although each device actually services one user at a time, the high speed and multiple components of the facility give the outward appearance of handling many users simultaneously. Multiprocessing tends to maximize the use of hardware. (Contrast with "batch processing" and see "time sharing.")

natural-language-processing mode Attempt to program the computer so that the student user may respond with terms and conventions natural to him, and little if anything about the system operation need be learned to use it. The ability to process natural language, and subsequently to diagnose and prescribe on the basis of statements made by the student without any constraints, approaches the realm of "artificial intelligence" and presently is quite experimental.

off-line Processes performed apart from the operation of the central processor of a computing system, e.g., decks of cards for a batch job being read onto an input tape for the central processor. (Contrast with "on-line.")

on-line Connected directly to the central computer, e.g., an electric typewriter in direct communication with the computer processor. (Contrast with "off-line.")

operating system The collection of programs (software) which direct or supervise the utilization of processing components and the execution of other programs.

partitioning Using a computing system as functionally divided into two or more subsets so that different tasks, perhaps batch processing and on-line processing, can be given different priority. That is, one subset may be programmed to respond rapidly to on-line users while the other works on lower priority jobs to be handled as CPU time and working space can be made available.

plasma panel A flat, gas-filled panel for display of characters and diagrams by electric signals. A plasma panel was designed at the University of Illinois to provide a durable, low-cost display device with some flexibility for writing and storing information at a student station.

polling A centrally controlled method of calling a number of points to permit them to transmit information.

port The physical facility for connecting a phone line coming in from a user terminal to the computer.

practice mode Computer use in which the learner is given problems and a facility for solving them, or is otherwise aided during successive exercises of a particular skill or technique. The practice mode of computer use is of much broader scope than simple drill.

problem solving mode The learner knows a language or notation that permits him to enter into the computing system data and the steps by which the computer might work out a solution.

programmed instruction A strategy for the development and validation of instructional materials which uses a step-by-step method (or frame-by-frame specification) for presentation of the subject matter. This strategy has been applied to the development of materials in various media including textbooks and computer-controlled audio-visual materials.

programming a) Instructional: the construction and arrangement of elements of a learning exercise and perhaps self-testing in a way specifically designed to promote effective and efficient learning; b) Computer: the construction and arrangement of elements of a procedure specifically designed to achieve a problem solution or to demonstrate a process. (See also "algorithm" and "flow diagram.")

RAND Tablet A metal writing surface developed by RAND Corporation for input of graphic information to a computer through use of a special writing stylus. (See also "joy stick," "light pen" and "mouse.")

random access Refers to a facility whereby information can be returned from any part of a storage device rapidly at any time. Diskpacks and drums are random access devices. (See "sequential access.")

real-time Performance of processing during the actual time the physical process transpires, in order that results of the computation can be used to guide the physical process. For example, real-time computing is required to determine the correction factor from telemetered data before a rocket is too far off course to be recovered.

remote-access Use of a computer from a station some distance from the central site of equipment. Remote access computing is usually accomplished through connection of a telephone line or other electronic transmission medium.

response time (system response) The amount of time which elapses between generation of an inquiry at a user terminal and receipt of a response from the computer at that same terminal. Slow response time for educational users of a computer system often leads to frustration with the instructional exercise and to dissatisfaction with computer aids. (See also "latency.")

RPQ (Request Price Quotation) Special equipment features which might be obtained by a purchaser on request but are not included by the vendor in his price lists. The RPQ designation permits a supplier to mention equipment additions and modifications (which might be useful in educational settings) without having to work out a detailed pricing policy before the demand is known.

scholarly aids mode Computer use in which the processor, procedures and data files are put at the disposal of the student as a scholar in the discipline. Scholarly aids might include information storage and retrieval, text processing and analysis, model construction and testing, and specification of complex displays.

sequential access (linear access) Refers to a facility with which the storage and/or retrieval of desired information may require some time to skip past large quantities of irrelevant information. Card readers and tape readers are sequential access devices. (See "random access.")

sign-on and sign-off (also log-on and log-off) The action of registering with a supervisory system (which may include billing procedures and records) for use of computing facilities, and a latter action of terminating the period of use. In a typical sign-on operation, the user types for the computer identifying information and perhaps a password which indicates permission to use the computing facilities and information files associated with that user identification.

simulation and gaming mode A conversation between student and program in which the results he obtains follow a model of a real or idealized situation. Simulations attempt to model some aspects of the real world for study and research. Computer-based games usually place the student in less realistic situations, provide specific payoffs, and introduce competition with other students.

skills practice mode See "practice mode."

software a) Computer: programs as contrasted with computer components. (See "hardware.") b) Instruction: curriculum materials as contrasted with computer facilities or people. Many people working on innovative computer uses see the essential problems to be less concerned with hardware (size of computer memory, speed of processing, and capabilities of user terminal) than with software (computer programs and curriculum materials).

station One of the input or output points in an information processing and communications system. A user station typically includes a keyboard for input to the system and a typing element for output.

storage The capacity of an information processing system to save information for future use; also used to refer to a system's storage devices. (See "core" and "disk.")

storage protect A hardware feature which prohibits one user in a shared system from inadvertantly using or changing information stored in memory allocated to other users.

student station Equipment designed for student use in interacting with a computer. A student station includes components for input (keyboard, light pen, mouse or RAND Tablet) and output (typewriter, typing mechanisms, image projector, plotter, CRT, or plasma panel). (See also "terminal.")

tape (magnetic or paper) Used for storage of information in computer system and on the shelf. The tape drive, having the physical appearance of an audio playback unit, is a serial access storage device; it takes some time to pass over unwanted information when searching for the unit of instruction a student needs next.

teaching logic A pattern (or strategy for instruction) into which various topics or sets of questions and answers may be placed. A number of teaching logics have been proposed; each "author language" implies another logic.

teleprocessing A form of information handling in which an information processing system utilizes telegraphic communication facilities. A student using a computer remotely via telephone lines is using teleprocessing.

TWX (teletypewriter exchange service) An automatic teleprinter exchange switching service provided by the Bell System. In a sense, TWX (sometimes pronounced "twix") is a special telephone network just for conversations between a teletype and a computer (or other teletypes).

telpak A service offered by communications common carriers for the leasing of wide band channels by the month (available 24 hours per day) between two or more points. For example, "telpack A" service provides the equivalent of 12 regular telephone lines in a package for the approximate cost of leasing four regular lines separately. Wide band communications soon will be available through switching (dial-up) networks with charges made by the minute of use rather than on a monthly rental basis.

terminal A point at which information can enter or leave a communication network; the I/O device used at that point. (See also "student station.")

text analysis mode Use of procedures for editing and analyzing text by an author to adapt learning materials for other users, or by a student to interpret and criticize work in the discipline preparatory to seminar discussion by a group of students.

tie line A private-line communication channel of the type provided by communications common carriers for linking two or more points together. A tie line is paid for by the month and available to the user 24 hours per day, point-to-point. (Contrast with "dial-up service.")

time-sharing The use of multiprocessing with emphasis on the convenience of the user who is running an interactive job. Although time-sharing applications imply a rapid interaction between user and computer system, some batch jobs (tasks prepared for processing at the convenience of the computer system and operator, perhaps with others in a batch) can be submitted to a computer with some convenience through a time-sharing system.

translator A computer program which accepts statements or instructions written in one language and produces statements in another language or perhaps direct instructions to the computer for execution. (See "compiler" and "interpreter.")

turn-around time The approximate time required for completion of a batch job, from submission of input (e.g., card deck) to availability of output (e.g., printed results).

tutorial mode Computer use for presenting exposition in which the author maintains the conversational initiative throughout by defining objectives and describing the subject matter in considerable detail.

voice grade channel A channel (e.g., telephone connection) suitable for transmission of speech, generally with a frequency range of about 300 to 3000 cycles per second. Digital or analog data, or facsimile reproduction can also be transmitted over voice grade lines (channels) if 3000 cps is sufficient for the signal.

WATS (Wide Area Telephone Service) A service provided by telephone companies which permits a customer to make calls to telephones in some distant geographic zone on a dial basis for a flat monthly charge.

word A set of bits sufficient to express one computer instruction (usually 12 to 60 bits long, depending on other characteristics of the machine). Usually the equipment is wired to transfer one or more words of information at a time.

VOLUME II

1. Introduction.

This second volume includes some of the working papers and other supporting materials of Project CLUE. It is not for a casual reader curious about computers and their uses in education; he should find that the tutorial material and guidelines in Volume 1 are more suitable.

Sections two through seven of this volume present the statements of position and points of view which were used to initiate discussion and provide a framework for argument about the accomplishments, needs and trends. These statements were not intended to present new ideas or evaluative summaries; they provide some reminders of what has been said, and serve as a guide to points of view for one interested in serious study of the field. Each section was assembled by staff of Project CLUE from published papers, unpublished technical reports and some personal communications. A draft was sent to each person referenced, and a revision was prepared using all replies received. A second draft was distributed to a select group of readers just before the annual meeting of the American Educational Research Association, February 1970, and discussed at a special session there.

The readers were quite critical of the position statements discussed at the AERA meeting which correspond to parts 2, 3, 5 and 6 of this volume. The major problems were paraphrasing out of context, implying equal value for the views of persons of greatly different experience, and confusing the reader by placing together conflicting views. Project CLUE staff attempted to correct the errors but chose to leave the statements nearly as they were taken from published literature, providing a sample of the literature as of February 1970, with all its faults, confusions and conflicting views.

Educational technologists and administrators reacted more favorably than the educational researchers; apparently the collection of statements does succeed in providing an interesting sample and pointing out differences of opinion on important matters.

Project CLUE December 1970

One of the important contributions of Project CLUE has been to bring together different points of view about instructional use of computers, including the different perspectives of researchers and practitioners, and to provide some common framework for discussion. This can be done without causing one point of view to interfere inappropriately with another, and without permitting conflicts to restrict communication. In fact, the contrasts brought out by the position statements and other documents appeared to have enhanced the climate for new thinking and exchange.

The appendices of the volume provide information about the mechanics of the study and excerpts from working papers. Appendix A describes the procedure followed and lists in some detail the formal dissemination activities. Appendix B lists all projects which were contacted during the study to obtain and confirm information about current activities. Notes on actions which might be taken by professional societies and other organizations to promote effective computer uses are included in Appendix C; the important role of the professional society justifies a separate study or conference or special dissemination activity. Appendix D includes information about the working papers on computer system and language design, i.e., the contents and introduction or excerpts; current source of the papers themselves has been included.

It must be emphasized again that these statements of points of view (Chapters 2 through 7) are not an evaluative summary of the topics named. The paraphrase of excerpts from the literature provide only a starting point for discussion by sampling different views expressed, especially as they appear to conflict in evaluation of the field and prescription for new directions of research and development.

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* These statements have been selected from published and unpublished literature to represent various points of view concerning operating procedures and costs. Most have been shortened and some altered to convey the intent in a few lines within the context of a larger outline, and to point out similarities and differences among related positions.

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Project CLUE December 1970

I. MANAGEMENT CONCERNS

A. Planning and Organization

Of paramount importance is careful and systematic planning which anticipates those obstacles one can expect to encounter in any innovative technological design. [Pagen]

Apparently many individuals planning new curriculum development or computer applications programs underestimate the requirements and benefits of careful organization and management. Many projects fail to complete and put into use a substantial set of materials primarily because of lack of planning. [CLUE staff]

Computers will never be useful in the schools unless these schools are drastically reorganized and appropriately funded to absorb reform. The discrepancy between ultimate promise and immediate possibility becomes apparent in the comparative examination of the properties of school systems and the properties of other social systems that have proved to be receptive to innovation. [Oettinger & Marks]

B. Administration

No one has yet faced the scheduling problems entailed by even the limited amount of individualization provided by the new technology. The increasing divergence of even an initially uniform group of students is considerable. It is probable that schools in the short time span of the next decade will be unable to take advantage even of the pacing flexibility of computers without the kind of major administrative revolution that seems conclusively blocked by other factors. [Oettinger & Marks]

Use of CAI without provisions for the acceleration of faster students through the school system is very costly; hence, CAI exerts a pressure favoring more rapid advancement of the better student. [Randall & Blaschke]

Administrators rather than technologists must lead the way in preparing for the new educational technology, and preparation must begin at the lowest "management" level, that is, in the classroom. [CLUE staff]

C. Personnel Needs: Recruitment and Training

1. Shortage and sources

One should not acquire equipment that may sit around unused for lack of technical personnel and other assistants. However many budding projects may be faced with what to do with money promised for facilities without personnel and without assurance of a line item in the budget for either rental or personnel in the following year. [CLUE Staff]

A critical shortage of qualified personnel can be remedied by efficient retraining programs which should in particular promote a new role for the teacher as a manager of instructional processes and tools. An important source of personnel may be the community colleges. [CLUE staff]

2. Teachers and the new technology

It is an absolute necessity that classroom teachers and the public schools be involved as full partners in the development of effective innovation in American public education. [Pagen]

Teacher fear, upon exposure to a CAI program, rapidly vanishes and is soon replaced by enthusiasm. [Prince]

Hardware and system development presently receive the major portion of available funds; instructional applications and training programs are assigned lower budgetary priorities. University teacher training programs do not meet the demands of the new technology. [CLUE Staff]

II. OPERATING THE INSTRUCTIONAL SYSTEM

A. Choosing a Type of System

1. Capacity and size

A small college may begin with one computer on campus, but as computing use grows and diversifies, a split into separate facilities becomes desirable. At a later stage it may be worthwhile to combine facilities again into a very large system. In any case, economics of size depend on use and management. [Viavant, Vol. II]

For instruction to be provided at a reasonalbe cost, the computer system must serve more than one purpose as well as a large number of pupils at the same time. [Prince]

A small group of users has four options: 1) rent time on someone else's machine for both time-sharing and batch uses; 2) buy a small computer for direct use by students and teachers; 3) seek out other small groups and together support a large machine for shared use; or 4) some combination, e.g., buy a small computer and also rent time on a larger, more flexible system for uses with more complex requirements. [CLUE Staff]

One solution to size and cost may be found in small computers working as satellites to larger systems. [CLUE Staff]

2. Purchase or rental

A primary consideration is the relative efficiency of a university vis-a-vis commercial enterprise in the provision of computer service. Simple economic arguments suggest that many universities should purchase or lease terminals, and allow faculty and students to purchase services from outside vendors, as their interests, needs and budgets allow. [Sharpe]

The cost of local operation of an instructional system which provides only one language may be much less than similar operations on a general-purpose system providing the user greater variety of capability. Nevertheless, the potential author who does not wish to commit himself to a specially designed educational system, or the school which wishes to gain some experience without large investments in space, leasing arrangements or committed user time, will find the rental of terminals for use of a general-purpose, time-sharing system to be a satisfactory interim arrangement. [Zinn, a]

The location of smaller computer satellites in schools will in some measure cut communication costs for a school system. The data processing computer at a central site is free to do prime time educational data processing. The information necessary to drive the small computers will be up-dated at night by a batch processing procedure. [Prince]

A large central facility serving many remote consoles is more economical than serving the same group with a large number of separate small installations. Such a facility under the control of a university also provides model courses, a spectrum of consultants, the basis for an effective training center, and remote access to the library programs of the central university-operated computation center covering the complete spectrum of computer application at all levels. Direct access to such a storehouse of knowledge means that the most shy and remote student in the least significant school with a remote console is limited only by his own ability in probing the most recent advances in computer science. [Lykos]

B. Equipment and Maintenance

It is important to know exactly what is needed and then to request that the manufacturer provide such a system. It is also important not to ask for things which the manufacturer is unable to provide you; this would force him either to withdraw from the bidding, or include in his pricing the cost of developing a product to meet your special needs. In addition, one should clearly define when payments for a system are to begin, whether it is being purchased or being rented. [Dick]

The development of innovative software and of new and more efficient procedures using system timesharing routines is an essential function of a project's operations. Records should be maintained pertaining to data on system and technical usage time and costs, as well as system and down time for both scheduled and unscheduled maintenance. [Bunderson]

If we are to continue the development of on-line, fast-response information systems, we must look for ways to provide service "all the time." As increasing numbers of people come to rely more and more on the use of the computer as a routine matter, we must impose a requirement that the system perform without "serious" interruption, especially during the hours between 6a.m. and midnight. In the university context, the question of reliability vs. maintainability is still not resolved. [Gordon]

III. PRODUCTION AND OPERATION COSTS: THE ECONOMICS OF CAI

A. Funding Considerations

Extensive use of computers for instruction in colleges and universities even if demonstrated to be more effective than conventional instruction, requires at least one of the following: a) instructional budgets will not be significantly greater than with conventional instruction, or b) Federal funds are available for general support of increased costs of higher education, or c) Federal or other outside funds are provided specifically for acquisition or operation of instructional systems. [Barro]

The necessary research and development can not be financed adequately with funds "stolen" from operating budgets. Proponants must persuade all those who are involved--taxpayer, legislators, trustees, administrators, teachers, students, parents--of the worth of what is being attempted for education. That will not be easy, since introduction of computers involves an increase in the total cost of education before unit costs are reduced to an acceptable level. [Gordon]

The introduction of computers need not cause an increase in institutional budgets beyond that anticipated for expanding enrollments and personnel costs if: 1) federal agencies and foundations provide for a few large-scale and high-quality research and development projects which are relevant to actual needs of various institutions;

2) private industry contributes to facilities and systems development, increasing the relevance for solving educational problems;

3) publishers and other private investors support development of a great variety of curriculum materials, sometimes competing for selection by well-informed users; and

4) private or federal sources induce initial demonstrations and continuing diffusion effort, perhaps through national commissions and professional associations. [Carruth and Prince]

Innovation can not be accomplished in three years. Government sponsorship of new programs must provide for the difficult transition from the development and demonstration to the operational status in the schools. [CLUE staff]

B. Factors Affecting the Determination of Costs

Prediction of relative use of computers in instruction involves such diverse variables as: the state of computer technology; the attitudes of participants in the education process; developments in instructional science; increase in costs of "conventional" instruction; changes in educational programs and curricula; future developments in higher education finance, and a variety of administrative and organizational considerations, as well as costs per student hour of use. [Barro]

Prediction of specific costs per student hour of instruction must be based on forecasts about developments affecting several aspects of CAI systems: hardware technology, software technology, instructional strategy, and the kinds of instructional material found useful. Perhaps most important, CAI costs will be strongly affected by the degree to which institutions are able to modify certain of their organizational characteristics, and to develop new modes of organization, where necessary, in order to make economical and flexible use of computers for instruction. [Barro]

Each week, the average teacher spends about ten hours doing "homework" after school. Since this time is not reclaimable by the school system, the teacher's salary must be considered, for all practical purposes, to cover only her time spent physically at school.

Costs of preparing recorded or programmed instructional material for presentation through technology-based systems cannot be justified by offsetting savings of teacher's time, since the specific time saved ("homework" after school) is a "free" resource contributed by tradition by the teacher to the school system and not reclaimable. Ways of profitably employing the teacher's free resources within the new educational technology must be found if the benefits obtainable from them are not to be lost forever.

[Randall & Blaschke]

Future costs of producing lesson material depend on technological developments such as improvements in CAI author languages and instructional strategies. Progress in the computer software field ought to reduce the cost of producing instructional programs of any given degree of sophistication. However, this may be offset if progress in developing instructional strategies results in more sophisticated, more responsive, and more individualized lesson material. Therefore, there are two considerations: 1) How elaborate a computer program will be required for each type of application? 2) How will future developments in programming languages and data structures affect the amount of labor required to produce a program of given complexity? [Barro]

C. Achieving Cost-Effectiveness

It is grossly inefficient to consider the use of a computer in a limited, daylight school day. The economic feasibility of CAI will obviously increase as the number of hours per day available for teaching is increased, because of fixed cost of hardware. Of course the current administrative model of instruction deriving from long-standing practices does not permit the extension of the school day. [Kopstein & Seidel]

The cost per student hour of instruction is a convenient but inappropriate measure of the efficiency of instruction. The basic defect is that student hours of instruction are a measure, not of the output from education, but the input of student time. When schools aspire to do more than merely "babysitting", this measure of efficiency is misleading.

[Posner]

Assessment of effectiveness requires the definition of a measure of accomplishment which avoids reliance on how long the student spends at a computer terminal. Studies of cost-effectiveness could proceed if the experts in some subject area would agree on measurement of concepts acquired or skills perfected, which would apply throughout the domain of concern. [Zinn]

The best justification for a high cost CAI instruction system is a high payoff. The most promising opportunities will come where traditional instruction has performed badly in an important task and where greater effectiveness has a high economic value. [Posner]

A project seeking cost-effective operations must seriously consider providing student and teacher access to the computer system at different levels of interaction and corresponding cost, from those requiring one-second response from the computer to ten minutes or an hour or a day. Perhaps the operating system should advise each user on how to get the most from his allocated resources. [CLUE staff]

On the basis of present anticipated costs, the financial investment required to install and operate computer assisted instruction will restrict significant use of this instructional medium. The need to form cooperative arrangements among school districts is indicated on the basis of cost alone. These arrangements should be determined by the numbers of students to be served without consideration of present local school district or state boundaries. [Booz, Allen & Hamilton]

CAI will be cost-effective first in adult education and training for skilled personnel. Many adults are "turned off" by a school environment. Individualized instruction is appropriate for adult audiences which are far more heterogeneous than the children in most schools. The opportunity to schedule learning outside of normal working hours is an improtant advantage which minimizes the disruption of work. [Posner]

D. CAI vs. Conventional Instruction

If CAI were to prove relatively ineffective, the degree of investment in it would have to be scaled down; on the other hand, if CAI should prove twice as effective and/or efficient as TAI, a cost as much as twice that of TAI might be acceptable. [Kopstein & Seidel]

The assumption of equal effectiveness of computer and traditional techniques is convenient but not essential for economic comparisons. Effectiveness usually is not equal; differences in effectiveness should be measured and integrated into the analysis when possible. Cost-effectiveness analysis techniques are designed for the situation in which conclusions must be expressed as trade-offs between incremental cost and incremental effectiveness, and they have the salutary effect of forcing measurement of effectiveness in spite of the hard work and non-trivial costs required. [Posner]

Cost analyses should not assume 100% facility usage at all times; scheduling flexibility, student absenteeism, or equipment troubles reduce effective use. For example, one operational project with a 20-station system reports 50 to 60% utilization. Furthermore, usage 12 months per year is not reasonable for many installations. [CLUE Staff]

It is unlikely that CAI will ever replace traditional instruction, rather it will be one of many learning tools. Cost comparisons should be made with other media (e.g., television or books) rather than with indefinite and encompassing "conventional instruction," of which media costs represent one part. Instead of replacing the traditional, computers will require an adjustment in the organizational arrangements of institutions, moving teachers and supervisors of instruction into new roles and functions.

[CLUE Staff]

E. Cost Estimates

1. For hardware

Communication with the central computer is a major cost of a remote access system. The development of inexpensive, wide-band transmission facilities would be of great value to all computer users. For short ranges, the investigation and development of inexpensive laser links may provide a solution to this problem. [National Academy of Engineering]

In the situation where a large number of students are located at considerable distances from the central computer, costs can be lowered drastically by use of a coaxial line instead of the equivalent capacity in separate phone lines. For example, the cost for a 4.5 MHz TV channel is approximately $35 per month per mile, whereas the corresponding rate for 1500 3 KHz telephone lines is over $4000 per month per mile. [Bitzer]

2. For software preparation

The production of high quality CAI materials is very time-consuming and expensive. The equivalent of a three-semester-hour course in high school mathematics takes many months to develop and the cost may run as high as half a million dollars or more. Of course, once it is properly developed and perfected, additional copies can be provided for other users for only a little more than the cost of the raw materials themselves. [Holtzman]

One often hears the figure of $10,000 per hour to prepare an instructional hour of CAI materials. Even in the most affluent case, it is difficult to see how this is derived. There are economical approaches to the preparation of CAI materials, as for 180 hours of seventh grade science materials prepared to closely parallel the informational structure and instructional strategy found in the classroom. The total cost of $34,865.00 yields an approximate preparation cost of $194 per instructional hour. [Hansen]

The total project cost for a collegiate CAI physics course developed at FSU, when spread over 40 hours of instruction (30 hours of regular material plus 10 hours of review), yields a CAI production figure of $5,980 per instructional hour. Of course the total budget included some one-time costs for auditions to the instructional system used. [Hansen]

Costs per curriculum hour vary considerably depending on the goals, manner of computer use, appropriateness of computer system, previous curriculum development in the area, and accounting method for attributing various costs. Criteria for cost estimates need clarification, and potential investors (sponsors, administrators and project directors) should view such figures with a critical eye. [CLUE Staff]

3. For student use

Data on cost per student hour can not be generalized because they depend on instructional goals, manner of computer use, appropriateness of the computing system used, skills and preferences of the author, local personnel costs, outside consultation, learning materials already available, and the method of accounting. The range of costs reported (perhaps 50¢ to $35 per terminal hour) only provides a very general framework. [CLUE staff]

The average public school spent an estimated $18 per pupil for instructional materials during the 1966-67 school year, or about 2¢ per student per hour. [Booz, Allen & Hamilton]

Cost, or cost effectiveness, in the short run is not the major consideration in a decision to introduce computers into the instruction and course development program of an educational system. The extent and scope of desirable changes brought about as a result of the introduction of computers and information processing certainly are worth some additional investment at this time. [CLUE staff]

IV. VIEW OF THE FUTURE

Responsive environments for learning will begin at infancy in the home as well as in special day-care centers. Children will be grouped from the age of three on and there will be no sudden entry into school. Most instruction will be individualized with a continuous diagnosis-prescription-evaluation cycle so that the student can gain mastery of basic skills as efficiently as possible. Learning resource centers with computerized libraries and communications controls will be the centers of education just as the library is the center of knowledge within our great universities. Study carrels or teaching terminals, however, will be remotely located for the convenience of students. The lock-step, self-contained classroom will completely vanish. While we may still have lectures from distinguished speakers, the current classroom scheduling system and sequence of courses on a semester or quarter basis will be completely replaced as the uniformly prescribed curriculum disappears. Computers will take over most of the drudgery of scheduling classes, allocating learning resources to individuals and groups, maintaining progress records while preserving their confidentiality where appropriate, compiling and scoring tests, providing easy access to files of information for reference or guidance by students and teachers, and a host of other management activities. [Holtzman]

The problems of engineering the transition from laboratory to mass production have only barely begun to be faced; the economies of scale necessary to bring costs within reason can be realized only through massive production and standardization; teaching materials to be used with such systems exist only in bits and pieces; and the people capable of forwarding the state of this are woefully few. [Oettinger]

A brighter future for CAI might be established through a partnership which includes industry, government and the education profession. Certain companies like hardware manufacturers, book companies, and computer software houses must be brought together in order to construct a viable CAI system. The educational community must provide subject-matter experts, demonstration and test facilities, and explicit goals. It has traditionally bee resistant to outside change but achieving full value of CAI involves commitment of dollar and personnel resources for large-scale R&D efforts and for massive training and retraining in the educational community. The central government is the only partner that can adequately and properly provide the funding and policy guidelines necessary: the financial investment is considerable; the effort must serve the public welfare; and the return on the investment may take much longer than industry profit and loss statements demand.

One method of implementing the proposed partnership is to establish a national center for research and development on innovation in educational systems, perhaps a non-profit corporation. The center's prime function would be to coordinate the application of diverse scientific and technological principles in the solution of educational problems. Research and development would be carried on at local installations employing different approaches with feedback to the center to upgrade the technology in general. A system of demonstration schools would be established to implement and integrate the R & D finding within practical costs, situations and constraints, and to disseminate information on recommended changes. **[Seidel & Kopstein]**

Machines decrease in cost as they are mass produced; early models of any system are usually maximally priced because developmental expenses are included. This has been true of both computers and television. However teachers' salaries follow the upward spiral of the standard of living. From the viewpoint of costs alone when the two lines for teachers and technology intersect in the future, teaching-by-technology may need to be considered in a new light and may be found to be far more attractive on a cost basis than it is today. **[Booz, Allen & Hamilton]**

Educators will have a great influence on the future of CAI, through their decisions about overall goals of education and about the technology requirements for reaching those goals. The focus on overall goals will yield a change in emphasis from method to specification of objectives, increasing the degree of measurement of the learning process. Such measurement in itself will greatly increase the rate of innovation in education by making clear the additional work that is required. Goals set for the learning process should also cause an expansion of education into other aspects of society, specifically in the home and throughout a career. [Bacon]

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3. Development of Computer-based Learning Materials: A Statement of Positions and Points of View.*

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*These statements have been selected from published and unpublished literature to represent various points of view concerning development of computer-based learning materials. Most have been shortened and some altered to convey the intent in a few lines within the context of a larger outline, and to point out similarities and differences with related positions.

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I. Modes of Computer Use in Instructional Programs

A. Considerations for Developing Effective Uses of the Computer

Effective curriculum development in any subject or group of subjects requires an analysis of the content leading to a choice of appropriate methods, media and sequencing. Thus in planning a course, each unit of work should be seen as contributing to a fully co-ordinated whole. In considering the potential role of the computer an essential pre-requisite is a complete analysis of the proposed course content so that computer facilities can be realistically exploited as a contribution to the whole.

The designer of a computer-based simulation or gaming exercise should give careful attention to specific instructional objectives and to the contribution of computer aids to their achievement if he hopes to document his hypothesis that the richer environment and greater responsiveness of the computer lead to many other desirable results in addition to acquisition of facts and basic skills which might be accomplished with directed study and drill. [Zinn c]

Potentially a very important educational use of the computer's capacity to handle data and to store and retrieve information is the presentation of complex simulation which it would be difficult, impossible, too time-consuming, or too costly to set up otherwise. It becomes feasible to extend the student's experience beyond the bounds usually set by current educational techniques. [NCET]

For certain students and some instructional objectives the effectiveness of a computerized, author-controlled presentation will be sufficiently greater than experience with the same content in textbooks or audiovisual materials to justify the greater cost per unit of instruction. For example, many children lack the verbal skills, discriminations, and attention span that may be needed for independent study without the aid of a computer; students of written and spoken languages in any age group may for similar reasons need computer assistance for diagnostic self-testing of skills. [Zinn]

Computer administered drill or practice has particular relevance to current needs in providing instruction for the disadvantaged child. Gaps in achievement between populations of the disadvantaged, which are presently hampered by the traditional educational program, and other children can be narrowed, although the technique may not prove of value in all individual cases. [Prince]

Although computerized drill may be good for remedial students, motivation is the key issue and the child might learn more if he wrote his own programs. Learning with the computer should be a creative experience, not a fully programmed exercise which decides everything for the student. [Loomis]

B. The Computer as a Learning Tool

A current trend in instructional use of computers is away from the programming of sequences to be delivered by the computer under strict control of the author's sequencing rules. Managers of future systems will probably make the primary sources of knowledge directly available to students through organized files of information and procedures; students will be given the necessary learning tools for information management, computation, and composition.

In using the computer as a learning tool, students can accomplish more scholarly work of greater quality during a given period of study and acquire more skill in searching for and organizing information than through discontinuous encounters with structured and strictly controlled tutorial instruction interspersed with periods of independent study. The development of curriculum files shifts the role of the subject expert from the detailed writing of a step-by-step introduction for a topic to the assembly of an appropriate data base for student exploration and to consultation on the development of powerful aids for exploration and scholarly work within those files of information. [Zinn a]

One of the most useful modes of computer use for physics instruction is computation: the students use the computer as a computer and with a standard programming language. Courses will be restructured to take advantage of this new and powerful tool. Too often people ignore this particular usage even though in some areas, particularly in the sciences, it seems to have more immediate potentiality than almost any other way of using computers. [Bork]

It is doubtful that CAI programs which look like lectures and programmed instruction texts could show significant gains in either time or achievement to justify the choice of CAI over paper-and-pencil or cheaper audio-visual materials. [Bunderson]

In educational activities should the computer control the child, or the child the computer? School boards and other public officials should insist on computer systems that provide each student with the chance to develop some minimum programming skill. The future citizen will be much better off in the age of the computer if he learns at an early age that he can and should control the computer. [Science Research]

C. Computer Aids for Instructional Management

When individuals are permitted to learn at their own rate, enormous differences in the time required to achieve certain performance standards are soon evident. As a result, practitioners in individualized instructional programs report that the instructors and aides become inundated with record-keeping activities. The need for a computerized management system is obvious in these settings. [Dick]

A more recent trend in instructional application of the computer is computer-managed instruction. Though there are several projects currently in progress, not one of them is far enough along to permit evaluation of this approach. Since the principal function of the computer in CMI is to prescribe and schedule, it could serve thousands of students daily, and the operational costs should be less than those of traditional instruction. [Morgan]

II. PROFESSIONAL STAFF INVOLVED IN DEVELOPMENT OF LEARNING EXERCISES

Various types of professionals are needed to make up the staff of a computer-based learning project. Many of these personnel will be specially trained in the new technology; others have managed to adapt their skills to meet new demands. A number of individuals must work together in order to develop effective uses of the computer in education. [CLUE Staff]

A. Administrators

Here are needed educator-businessman types literate in computer lore. Also, there must be a higher management which encourages an environment for continuous progress (self-paced) learning in other aspects of the educational or training system as well as CAI components. [Bunderson]

An administration sympathetic to the goals and knowledgeable about the costs and other demands of careful development is essential to success. Furthermore, enthusiastic administrators sometimes carry along an already overworked staff when funds, computer resources, and personnel are otherwise lacking. [CLUE Staff]

B. Operations and Systems Staff

This group includes a supervisor, operators, system programmers, and proctors for terminals. [Bunderson]

Operation of an instructional resource is a peculiar task. Nevertheless the experience gained from struggling to meet varied needs at some other resource center is invaluable. [CLUE Staff]

C. Subject Experts and Teachers

One needs excellent, talented scholars who can assist in the task analysis. These content scholars will find themselves interacting primarily with the behavioral scientists associated with the project. [Hansen]

Teamwork between scholar-teachers and CAI specialists will be required. The former will confirm the analysis, suggest and develop the major representations, and author the basic steps of the program. [Bunderson]

Suitable networks will stimulate and assist groups of subject experts who work together on computer-based materials for the same course at different schools. Materials developed on a cooperative basis will be more usable at different institutions than if they were developed independently. [Zinn]

Curriculum development of all kinds requires the active collaboration of teachers and lecturers in the field. Teachers must explore and exploit the possibilities of the computer for it will be only through them that effective innovation can take place. [NCET]

D. Evaluation Specialists

The techniques for assessment of outcomes, especially for feedback on effectiveness of material during the development process, are involved and require experienced personnel. [CLUE Staff]

In summary, the functional skills required are the result of backgrounds in educational psychology, experimental design and statistics, author-teacher experience, instructional programming, instructional coding, familiarity with computer assembly languages, computer operation, administrative coordination, and supervision. A team is needed to make efficient use of a system, and would be adequate to handle several subject-matter experts, each of whom must have sufficient ability talent and expertise in his field to warrant the expenditure of time and effort.

E. Computer scientists

The cross-fertilization between system analysis and computer programming and curriculum design for CAI may yet produce a decisive advance in education just as mental cross-fertilization between different disciplines has contributed to all decisive advances in the history of scientific thought. [Bunderson]

F. Educational psychologists

Instructional designers will help by suggesting representational ideas appropriate to the interface, prompting with heuristic questions suggested by the design model, developing system architecture in close cooperation with the authors, filling in details, and supervising the coding, media preparation, and program documentation and maintenance. [Bunderson]

Learning systems analysts should be members of a team working with subject experts and able to gain a quick understanding of the subject; identify flaws in reasoning of logical presentation; determine for specific skills whether current methods are the best available; prescribe a skeleton form for the material; play the role of a student; decide on the most suitable mode for presentation media; turn analyses and prescriptions into working programs. [NCET]

G. Learners

Although initially considerable weight should be given to the opinion of experts in the subject area, eventually simulation uses of computers for instruction should be submitted, as are other uses, to a careful analysis and evaluation in terms of learner performance and attitude. [Zinn c]

Uses of an interactive language make the program more accessible to the student, increasing the opportunity for him to become involved in the redesign of an exercise. This is especially important when the curriculum writer has incorporated mathematical models or simulations. [Zinn a]

III. MODELS FOR INSTRUCTIONAL DESIGN

A. Need for Explicit Models

Models must be explicit if we are to make progress toward a technology of instruction. [Zinn a]

A more effective and economical generative teaching system can be developed by establishing an explicit model of the human tutor who operates in a generative, algorithmic or creative fashion and then simulating these operations. [Uttal]

One of the major problems with instructional strategy is the lack of prescriptions for instructional design. There is no adequate data base from which to derive prescriptions in any one curriculum area, and no generally useful prescriptive rules are found in instructional theory. [Zinn b]

Certain professors highly regarded in their fields appear to be more productive without the constraints of an explicit model for instructional design although their consistent performance suggests some implicit model. [Zinn c]

B. Usefulness of Detailed Prescriptions

Things to be learned from the original notions of programmed instruction include: (a) the sequencing of events to set up the increasingly precise forms of response defined as subject-matter competence; (b) the significant process of the sequencing of instruction to establish and transfer stimulus control (the expert in a subject-matter makes precise responses to fine descriminations, and he is, in this sense, much more under the control of the nuances of his subject matter than is the novice); and (c) sequences which involve the systematic withdrawal of the learning supports required by the novice so that the behavior of the expert becomes increasingly self-sustaining and is maintained for long periods of time without the external support of aids and references required by the novice. [Glaser]

In order to achieve the benefits of separating procedure from content, the empirical derivation of practical strategy should be of considerable interest to educational psychologists. Given a set of techniques which work, and some parameters for adjusting or tuning them to individual problems and students, the educational researcher has a much more powerful tool for conducting research. [Zinn b]

C. Contribution of Continuing Research

The existence of individual differences (learning styles) and kinds of instructional sequences which must be designed for them can be discovered on the basis of CAI experience, but only if instructional sequences are set up in an experimental enough fashion to allow these differences to emerge. [Glaser]

Many interesting aspects of an instruction strategy may be hidden in the implicit understanding a human may have concerning the subject area and student characteristics. Requiring materials and strategy to be developed through the filter of a programming language assures that procedures will be explicit. [Zinn a]

One of the major problems with instructional strategy is the lack of prescriptions for instructional design. Perhaps there is some hope in the additional power provided by generative techniques, since designers will be more likely to identify and manipulate significant parameters. [Glaser]

One major problem with striving for learner achievement and efficiency is the lack of suitable units for measuring competency in a subject area. When the major purpose is to determine the relative standing of students, units need not be an important consideration. However, a report on the efficiency of a strategy or medium of presentation should try to say that so many units of competency were acquired per unit time. [Zinn b]

An instructional design model should provide a context for basic and applied research, generate questions, and offer an incentive for researchers to seek to develop answers to research questions in a manner which can translate to instructional design practice in actual curriculum projects. [Bunderson]

D. Other Considerations for Developing a Model

Psychological models provide a framework for research on instruction, but are relatively sparse in content and lacking almost entirely in prescription when compared to human insight based on considerable experience in supervising individual and group learning experiences. Among CAI researchers, Stolurow and Bunderson have done more than most using models, and both have at times spoken enthusiastically about prescribing different treatments (curriculum tracks or sequencing techniques) for individuals of differing characteristics or performance. However, neither can demonstrate success in such prescriptions, and the prospects are less encouraging now than they were five years ago. The problem might be characterized as having to know more about the learner and his study skills than he knows about himself, or applying computer control techniques to learners who are unable or unwilling to use the information about the subject matter organization and their own progress which is provided by any reasonable supervisor of a self-instruction environment.

> In the absence of not knowing more about the learner than he knows about himself, an alternative plan is to grant to the learner the freedom to organize his way through "knowledge spaces" and let the computer track him. The operational routes through the course, as supplied by the computer, will greatly aid educational researchers in developing such a theory of instruction. In addition it makes learners responsible for their own actions and management of learning, which is almost totally lacking in educational systems of today.
>
> [Grubb]

It is not to be implied that techniques of research and development in behavioral sciences have not benefited instructional technology; rather, we have derived as a result better tools and methods for development, presentation, and evaluation of learning exercises (whether computer-based or otherwise). Nevertheless, we have only empriical techniques without models of the learner or of instruction to put within an automated system.

It may not be wise to make a stronger statement about using mathematical (or information processing) models in a computer-based system today. The aspirations of early workers (Smallwood, Atkinson, and Matheson for example) have not been realized at least in practical terms. However, the nature of the automated system (large memory, detailed performance data, and rapid processing of logical and/or mathematical relationships) is better suited to mathematical, logical, and structural approaches than to descriptive or heuristic ones.

Although it must be an over-simplification of the contributions of the two classes of models, it is recommended that behavioral-science models be applied to the human components of a computer-based instruction system, e.g., orienting the teacher, counselor, and manager to the individual resources and requirements of learners. Information-science models should be applied to the machine components, e.g., arranging the information in a way accessible to the learner via the system and coding the feedback information and control mechanisms. [CLUE Staff]

IV. ANALYTIC TECHNIQUES

A. Task Analysis

Task analysis should tell what needs to be taught in subject-matter terms as well as identify the kind of behavior involved. [Glaser]

A task analysis of the curriculum concepts to be taught to the student should be performed. In simple terms, the task analysis should reveal an outline of the curriculum structure as it is to be taught. [Hansen]

B. Initial State of Knowledge and Skills

Entry behaviors are the skills and knowledge which have already been attained (by the students for whom the instruction is intended) that are relevant to the task which is to be taught. They describe where the students are now. [Dick]

The information about the task and about the student's entry skills should be taken into consideration in order to formulate the behavioral objectives. In fact, task analysis and entry behaviors are the primary determiners of behavioral objectives. [Hansen]

Entry behaviors should indicate where the students are at the beginning of the course, and the task analysis should characterize the various conceptual topics to be mastered by the students. [Hansen]

C. Hierarchies of Knowledge and Learning Tasks

The hierarchy forms the basis for the design of individualization and its description in flow chart form. The list of objectives is the basis for the specification of interface requirements, the diagnostic and curriculum-imbedded tests, and the terminal parts of the sequence of steps for each sub-objective. [Bunderson]

The behavioral objectives should be structured within a sequence which reflects one's pedagogical strategy. The instructional strategy to be employed should relate to a hypothesized set of psychological states through which the student would pass. [Hansen]

With respect to individualization of instruction, a hierarchical analysis provides a good map on which an individual student may be located. [Glaser]

The hierarchical analysis procedure seems readily applicable to any cumulative subject matter like mathematics, much of science, and even music. It seems less applicable in highly verbal areas. [Bunderson]

D. Implications for Representation of Knowledge

Empirical data obtained from learning hierarchies might influence the way in which knowledge structure has, heretofore, been represented. [Glaser]

In sum, the student taking this course soon realises that he is like a man using a motion picture camera equipped with zoom, pan and tilt features. Successive stages of magnification of the subject expose more and more details while panning and tilting keep the structure and perspective intact at all times. Symbols attached to each map inform the student of the level of magnification. [Grubb]

V. Documentation of Instructional Programs

Readable descriptions of content and strategy are essential to economical maintenance and effective use of computer-based learning materials. Widely adopted guidelines for documentation will broaden the base of users of effective instructional programs. (See Part 7 and Appendix C of this volume.)

VI. A VIEW OF THE FUTURE

It is likely that by the early 1970's the simpler forms of CAI will be in full operation in many schools. The more highly enriched tutorial CAI will spread more slowly largely because of the amount of effort needed to develop it properly and the relatively high cost of implementation. By the mid-1970's, however, it should also be fairly commonplace in settings where the effectiveness offsets the cost. [Holtzman]

The first successful application on a broad basis of computer-assisted instruction at the tutorial level will probably be at the secondary and college level of elementary foreign-language teaching. [Suppes]

The development of a free-choice delivery system for CAI, particularly into the home, will ipso facto free learners, of all ages, from the institutional requirements of conventional educational institutions. As a consequence of such a free-choice development, most educational institutions will eventually change to become more responsive to those they serve or wither away.

Thus, CAI has the potential of being a major liberating factor in education. As such, it will not be unique. Technology certainly is a double-edged sword; in addition to the constrictions it places on our lives, it can greatly increase our freedom. [Kyle]

Computer and information sciences will provide eventually a kind of "artificial intelligence" to be applied tin the teaching-learning process. The resulting systems will serve both the scholar as an author and the learner as a scholar, whatever the discipline of study. [CLUE staff]

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4. Programming Languages and Implications for Instructional Strategy: Statements of Position or Points of View*

7. ASSESSMENT OF A LANGUAGE AND SYSTEM

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2. Samples of code, presumably typical of user and task requirements 6
3. Empirical measures of usefulness: programming time, errors, attitude, execution time, etc. 6

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2. Instructor (supervisor or manager of learning) 9
3. Counselor or administrator, if different from the instructor . . 9
4. Author or lesson designer 10
5. Researcher on instruction and learning 11
6. Researcher on the systems and information sciences 11

C. Suitability for the Mode of Computer Use

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2. Computerized programmed instruction 12
3. Diagnosis and remediation 13
4. Question answering 13
5. File and text manipulation 14
6. Numerical problem solving 14
7. Graphic display 15
8. Other modes not defined here (i.e., growth potential to meet unanticipated user needs) 15

*These statements were selected from published and unpublished literature (sources are given at the end of the section) and paraphrased to convey the intent in a few lines within the context of the larger outline and to point out similarities and differences among related positions.

Because many of the statements were taken from a comparative study of programming languages, already a distillation of points of view, the list of references does not include primary sources. The interested reader should consult the original study (Zinn, 1969a).

D. Suitability for the Style of Program Preparation

1. Description of successive frames or items 16
2. Provision for conversation within a limited context 17
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I. ASSESSMENT OF A LANGUAGE AND SYSTEM

A. Representations for Language and System Characteristics

The forced juxtaposition of two or more languages, whether by a list of aspects, characteristic samples or measures of author performance and satisfaction, cannot help but encourage each designer to improve the capabilities of his language at least for those purposes represented in the comparison.

1. Functional aspects compared against a standard list

The comparison of languages by the 60 "common aspects" in the Educom comparative study emphasized similarities by presenting together the way in which 40 different languages would be used to accomplish the same function. Such discussion prompted some language designers to fill in a few blanks in the columns describing their languages; that is, they added to their own language some of the capabilities previously described only for other languages in the comparison table.

A summary table arranged by common aspects cannot be complete and free of error: the languages are changing rapidly; the designers are slow to provide current documentation; first-hand programming experience in each language is not possible. Different approaches to summarization favor one language or another; and more important, different approaches to instructional use of computers require essentially different language characteristics.

Languages explicitly intended to serve different instructional programming tasks should be described for the purpose of comparison by different sets of attributes in different tables.

In other words, programming tools should be grouped with others of similar purpose when making relative compairsons, rather than thrown together with all the tools of very mixed purposes.

When making decisions about languages and systems, the relative weighting of various criteria must be determined by each project or user, considering: a) the age and background of the student or other users; b) the relative importance of research, development, implementation and operations; c) the relative interests of project staff in general system characteristics, programming languages, or instructional materials; and d) the availability of funds and of a general-purpose system.

Some standard format or common notation is needed for writing an individualized description of each language so that its characteristics can be interpreted readily by interested persons who did not participate in design of the language. In order to communicate with potential users of computer-based systems, a notation for description should be readily interpreted by those who have little experience with languages and systems.

2. Samples of code, presumably typical of user and task requirements

The best test of a programming language is through use, and the closest approximation for a reader not yet familiar with the language is a sample of use on standard test situations.

Each language has unique features, and any small number of test programs will favor one or another. It is difficult to represent the capabilities of any language in a few pages of sample programs.

Many of the languages continue to be changed, and the samples obtained one month may not be characteristic of what is being done with the language six months later.

3. Empirical measures of usefulness: programming time, errors, attitude, execution time, etc.

Efficiency of a language sometimes is measured by the number of machine language instructions, source language instructions, characters in the file, etc. However this measure depends on the instructional strategy employed, the propensity of the author for writing the same learning task description in a smaller number of instructions, and his concern for providing responses for a number of rather unlikely eventualities.

A major problem for evaluation of any component of an instructional system is the definition of a measure of accomplishment which avoids reliance on how long the student spends with the new learning materials. The productiveness of an author should be measured by concepts acquired by the student (or skills perfected), rather than by hours the student spends at a terminal, as if the system were babysitting.

An effective system will encourage curriculum designers to exploit the computer medium to improve and expand the content and skills taught, and to use the occasion of revision to drop some material which is obviously useless.

Criteria for judgments about languages should be more explicit. Words such as reliability and flexibility are used as if everyone agreed on what they mean; in fact very different measures of the implied concept have been employed. It is not necessary that all writers agree upon any single definition for a term or a unique measure for a criterion, but each writer should make his use of terms and measures more explicit.

Journals should adopt a firm editorial policy which requires clarification of the referent or measure of "power", "elegance", and other such terms when used in published reports.

B. Suitability for the Primary Users, Considering Background and Goals

User performance (e.g., error rate) is an important consideration in the selection (or design) of a language. Increased training may not be the solution; programming errors which appear frequently in instructional programs can be reduced by changes in the translator.

One should not always blame the user for programming errors but look at factors in "reliability" of the semantics and syntax of the language. The same applies to reliability of the instructional program. Some of the errors which may occur during instruction and interfere with learning by an individual student should be blamed on the author, or the language designer, etc., not on the student.

1. Student

Students need to be able to get information about the system operation and procedures at any time: Is it operating? Why was his message not accepted? How long might he have to wait before starting a certain exercise? Procedures should be simple, including conventions for erasure within a message or cancellation of entire blocks, indication of availability of a device for input, etc.

The student of a particular discipline should not have to acquire computer skills and conventions which are unnecessary for his study, e.g., complicated keyboard skills or new notational conventions unrelated to the subject of study, and necessary only to reply to a computer tutor.

The information processing capability of the computer should be as available to the student as it is to the lesson designer or the researcher.

Computers and programming are now becoming part of everyday life, and the designer of a computer-based lesson should not hesitate to require of the learner certain computer skills otherwise unrelated to learning in that subject area.

2. Instructor (supervisor or manager of learning)

The system (and language) should accommodate the instructor, to the extent that he is expected to adapt the learning materials for each group of students and his particular style of teaching.

The right data on student performance and attitude should be available to the instructor at the right time and in the right context; relevant, timely and interpretable information is essential for effective management of learning.

If the system is designed to run without intervention of classroom teachers or other supervisors, then computer memory space and processing time should not be wasted on features included only for these personnel who do not use the system in operation.

3. Counselor or administrator, if different from the instructor

Management working from a perspective different from that of the teacher may require data in a somewhat different format and context: the counselor needs detail on individuals and in the context of other work or plans of that individual; the administrator needs detail on use of resources (personal and technical) in the context of the total instructional system.

An on-line data management system for school records would more than pay for itself in saving administrative time and reducing errors in quick judgments.

Most of the decisions which are made in educational systems do not justify on-demand access to current data; decision points can be anticipated, and many of them are periodic.

4. Author or lesson designer

Staff on a curriculum development project require convenience and predictable operation for writing and testing exercises; these requirements may conflict with the economy and convenience required for day-to-day student use in the schools. Terminal devices provided authors are more expensive; the speed of compilation of new programs is more rapid; priority is given to revision of materials, etc.

Data obtainable from student use of learning exercises may be selected and arranged differently for the purpose of revision of the exercise (by the author) than it would be for assessment of student performance (by the teacher or administrator.)

System designers should leave many options for the author. As examples: the user may prefer off-line to on-line entry with immediate diagnostics; he may wish to establish some of his own notational conventions rather than always to adopt those of the system programmer who designed the language; he may wish to change the standard replies (such as from "wrong, try again" to "not recognized; try again"), or to adjust the tolerance for accepting misspellings or typographical errors in otherwise correct answers.

Although there are many tricks that can be played with the counter registers and character registers of "author" languages, the lesson designer must apply peculiar commands for manipulating these rudimentary elements of information processing by computer. Playing these games will distract otherwise effective authors from their primary purpose: helping learners in some efficient fashion.

A procedure for presenting curriculum materials should be prepared by expert programmers according to a design developed by a team of subject experts and educational technologists; then the writers enter material into a system which in part can protect them against their own errors.

5. Researcher on instruction and learning

An educational researcher is willing to pay much more per terminal hour than an educational administrator, if the system provides the required facility for stimulus presentation and data recording.

Research uses usually require more detailed data than teaching and curriculum development, and some data are unrelated to teaching purposes: latency, physiological measures, etc.

In some research uses the computer makes no contribution to learning by the subject during the experiment; the researcher need not be concerned about computer-base instruction contributing in some way to the learning of the student beyond what would have been achieved without the computer.

6. Researcher on the systems and information sciences

A project on language characteristics and system features must invest in flexibility, even at the expense of author or student convenience. The curriculum writers who choose to work with such a project must be willing to give up convenience for the sake of experimentation, e.g., adjust to language changes, accept errors and unreliability, and modify or discard outdated programs.

An experimental system may be entirely different from an operational one with respect to relative costs, responsiveness to different users, etc.

Some day the experimental and operational purposes can be brought together in the same system.

C. Suitability for the Mode of Computer Use

1. Routinized drill and testing

A system used for drill and testing should have a library of standard routines which can be adapted for whatever pool of drill or test items the user might like to introduce into the system.

A user should be able to add readily to the library of routines or procedures for drill and testing.

The description of data (test items) for standardized routines should be straightforward and convenient for the author.

2. Computerized programmed instruction

A system used for presentation of programmed instruction materials should not require of the author much more than a specification of the text materials as they might be presented in booklet form rather than on the computer.

When variety is required it should be introduced at random or according to parameters under the author's control, e.g., selection from a set of confirmatory replies or options to introduce review material.

Frame-by-frame writing of programs with an author language is on the way out. A few years from now less than one tenth of any computer-based course will be programmed by an author or his technical assistant frame by frame in languages such as COURSEWRITER and PLANIT.

3. Diagnosis and remediation

A system intended to provide attention to difficulties of individual learners must have some generalized procedures to apply each time an answer is incorrect; full programming of each frame of a diagnostic test for all possible student difficulties is not feasible for the major part of self-testing and remediation exercises.

Diagnosis and remediation are important uses for computers in instruction, for the student is likely to benefit greatly from the opportunity for interaction with a prepared procedure. This mode of use places correspondingly greater demands on the programming language employed.

Standardized learning materials can be presented effectively by other media than computer-based systems. The more expensive information processing devices and programming languages should be applied to those situations such as remediation where individualization is not only desirable but necessary.

4. Question answering

Being a device for storing, processing and retrieving information, the computer should be programmed to assist the individual learner in his own scholarly endeavors by providing answers to questions about information sources, facts, etc.

One general approach must be applied to many topics and learning exercises if expensive question-answering systems are to be practical.

The expensive systems, designed to respond to inputs of great variety and be applied to a wide range of topics, become practical when the field of inquiry and the format for questioning are suitably restricted.

5. File and text manipulation

Handling files and strings of text is not a process incidental to computation, but a substantial part of information processing sciences. In the educational setting this mode of use should be accorded full attention in the library of programming languages made available.

The lesson designer (or the student as a direct user of file information) should not have to manipulate textual information with primitives applied only to characters and lines. Languages should allow suitable representation for units such as words, sentences, paragraphs, and chapters as well, and for search and transformation operations.

6. Numerical problem solving

A conversational problem-solving language such as APL, BASIC, or CALCTRAN would be much more successful on a regional computing service than an author language like Coursewriter. The development of high-quality tutorial instruction requires a major commitment of funds and personnel, including instructional designers, media specialists, and programmers not usually available at remote locations. Typically, one person at a site, almost never on a full-time basis, must give demonstrations, teach programming and consult on applications. An interactive computing language can be more easily taught and more effectively used with limited resources.

The problem-solving mode will be over-valued and misapplied, as was COURSEWRITER five years ago. However, more instructional materials of significance are likely to survive in this mode in the next five years than have been seen in the computerization of programmed instruction in the last five years.

Undirected use of a simple programming language is not always a cost-effective way to develop skills in problem solving or conceptualization of procedures. The designer of a learning exercise or environment must consider adding language features specific to the tasks the learner is to carry out, and try to describe ways of assessing the learner's progress along any path to a solution, perhaps specifying interruptions to provide information about difficulties encountered.

The special contributions of interactive mode of use to student programming and problem solving are not obvious. Much of what is said to be unique to interactive processors can also be accomplished with well-conceived compilers in a system providing very quick batch response. [See VI below on interactive mode contributions.]

7. Graphic display

Although graphic capability is much sought after by many computer users presently restricted to alphanumeric displays, those who do have the technical capability to show the student line drawings and accept simple sketches in return find the associated programming task horrendous. Programming problems in this domain have not been solved for instructional users.

8. Other modes not defined (i.e., growth potential to meet unanticipated user needs)

Other modes of use may not be included in the listing above, and many new uses are yet to be contrived. Each places special demands on the programming language and system which should be met if teaching and learning are to proceed in an efficient and effective way. Computers and information processing should be at the disposal of the learner and others in the educational system, and programming languages should be adapted to their purposes.

No language can be expected to have all those features which may be desired by various users. Most languages provide for definition of subroutines (separate routines designed for repeated use) with a transfer statement which saves the present location (or any designated location) so that control can later return to one of the saved locations. Macros provide another way to avoid repetition in coding by packaging a number of statements to be called on by one statement, in some cases with parameters. The facility for adding new operations or statements is less common but potentially very significant.

Some languages allow the programmer to write special functions, perhaps in another language, with a list of arguments automatically transferred from one to another. Ideally, programs written in any other language could be linked to an instructional program so that data could be passed from one to the other when the student moves from one to another (e.g., from tutorial to a special simulation or model building package).

D. Suitability for the Style of Program Preparation

If the programming language capabilities and conventions are not matched to the instructional programming task, exploration of new curriculum objectives and learning techniques will be suppressed, and large scale development of materials will be discouraged.

1. Description of successive frames or items

More instructional programming has been done by preparation of frames than any other approach, and most special-purpose "author" languages provide well for this style. However, additional provisions for establishing normal modes of operation or calling on standardized procedures would reduce unnecessary repetition in the instructional programmer's task.

The most straightforward approach to serving the needs of an author may be to provide a format into which he places elements of the curriculum. The computer program successively presents the question frames, provides a hint when the student asks for it, provides the right answer when needed, and records performance data for later inspection by the author of the exercise.

Frames of instruction or items of tests can be adapted as a kind of computerized programmed instruction. The similarity of the code and conversation to a programmed text is apparent. In fact, translators have been written to accept linear (or simple branching) programmed text and derive CAI interaction with a student.

2. Provision for conversation within a limited context

Authors should be able to compose complex, conditional procedures more easily than at present; MENTOR and PLANIT include good examples of convenient conditional expressions by which a procedure can be made dependent on student performance. Most authors of computer-based instruction have made little use of computer logic and memory, perhaps because they are unable to conceptualize complicated sequencing rules, or because they are quickly discouraged from doing so by the clumsy syntax of programming languages prepared for them.

Programming for conversation in relatively unconstrained English may not be a reasonable approach until some breakthrough in research on processing natural language provides an efficient and reliable means for "understanding" or at least classifying what the student says.

3. Description of a standard procedure by which material is presented

Content should be prepared in a form independent of particular computer conventions and convenient from the viewpoint of a context specialist. The control procedure which administers a learning task should be free of specific content material. The answer processing and other conversation-handling aspects of control should be separate from the scoring and sequencing algorithms.

Computer programs which assemble instruction materials from elements of the subject matter and relationships among those elements should permit the author to describe an entire class of problems by one set of statements. From one general description, an indefinite number of test or instruction items should be generated for presentation to each student as needed. A procedure which assembles or generates materials is likely to have more possibilities of adapting to the individual than one which selects successively or branches through a large pool of specific items.

Increased use of procedure-statements and (separate) curriculum files will be beneficial for the field, and increasing use of computers in large curriculum projects will require this approach for economy.

Procedure-oriented languages are for computer programmers and for educational technologists specializing in computer applications; these persons should produce the user-oriented languages or data formats which maximize convenience of the curriculum expert.

One could have too large a library of strategies and too much individuality among students and topics for standardized techniques to be useful.

Until instructional objectives for a topic are rather well defined (for example by standard procedures for testing use of facts, concepts and simple skills), development of prescriptive curriculum for individualized instruction in that topic is not likely to be successful.

The practical application of standard procedure programs and generative techniques applied to curriculum files on any specific subject area or training situation raises many questions: How are information structures to be described by the subject expert and stored in the computer for use in such procedure statements? How are materials to be assembled according to general rules? How is input from the student to be processed in some general way which determines a suitable reply? Can patterns or sequences be identified which prescribe certain adjustment for the student on succeeding learning experiences? Can the program improve itself?

4. Specification of an environment for programming and problem solving

If an on-line problem solving language is suitable for simulation and model building, then that language certainly is of interest to designers of computer-based learning environments. First, the subject expert may build models on which to base games or simulated practice for students to try. Second, he may guide some students through revision of the models and construction of new ones. In general, he wants to show students how to use the computer for information processing in his discipline; as lesson designer he might produce a "mentor" which advises each student on how to get maximum value from the computer as a problem solving and scholarly aid.

The most significant contribution of simple, interactive programming languages may be through increased student use of computers for problem solving and scholarly endeavor on individual initiative.

E. Implementations Available: Machines, Memory Size, Costs, Reliability, etc.

Variations among machines, even different models of the same machine, will affect the language features, efficiency of operation, number of users, and even the kinds of use.

Knowing that a language processor is available for a particular machine, say an IBM S/360 Model 50, is not enough. The specific configuration (computing resources) assumed by the language designers must be detailed: amount of core memory, special features such as memory protection, number of disk and tape drives, terminal controllers, etc.

Different implementations of a language processor, even with the same functional specifications and for the same configuration of the same machine, will vary in processing capacity and cost of use.

Assessment of the reliability of a particular implementation of an instructional language and system should consider the rate at which new errors had been appearing as well as the number of presently known errors. Although a programming system might be delivered with all known "bugs" fixed, the continuing appearance of three new ones each week thereafter would hardly be tolerable.

F. Documentation, Teaching Aids, and System Maintenance Available

Complete and interpretable manuals are essential for various users. Such reference materials can be incorporated in the processor (computer programs) to be printed out on request or as they appear to be needed, but in the past such an approach has been expensive and incomplete. Computer-based manuals continue to be attractive, especially for the experimental language which is continually being changed, making difficult the maintenance of current information in printed formats.

An introductory manual or primer for a language and system reduces the need for costly live instruction to initiate new users. Primers have been written to be used while working at the terminal of an interactive system, inviting the reader to test each new convention or concept as it is described in the text. Such self-instruction has also been presented by films or video tapes at somewhat greater expense and lessened convenience.

Adequate documentation of system programs often is lacking, making maintenance or improvements very costly or impossible (without reprogramming large sections of the processor). An institutional user should be satisfied it has descriptive materials for its systems programmers, or a tight contract for maintenance from the software supplier.

II. GENERAL IMPLICATIONS OF A LANGUAGE AND ITS IMPLEMENTATION FOR STRATEGY OF INSTRUCTION

A. Data Available for Automatic Decisions

If the system is not capable of measuring the time each student takes to respond, and making this available for decisions at the moment as well as later, then the lesson designer is denied this data for his instruction strategy.

Performance and preference records accumulated one day should be available the next day or the next month from some strategies of instruction. Records of individual learning characteristics may be more significant in selecting or arranging a later learning experience, than in phrasing the next question or diagnostic within the same exercise.

Some lesson designers have wished to pass information from one student to another, or provide summary information for all, whether for normative information about the learning task or for communication within a many-person game or simulation monitored by computer.

B. Processing Capability, Handling Character as Well as Numeric Information

C. Adaptability to Specific Tasks, i.e., Convenience for Describing Models, Drawing Diagrams or Retrieving Information

D. Generality of Procedures, e.g., Separation of Procedure from Content, and Generation of Material from General Rules

Instructional programs in which the content is described separately from scoring and control procedure are easier to prepare and modify than those in which all functions are combined in one set of statements. The content can be altered or replaced without changing the algorithms and conversely, and relative effectiveness can be studied as a function of the setting of control parameters, etc.

For some learning exercises, the writing of such a rule to generate a large number of variations will prove more efficient and accurate; a larger number of items may be described more quickly than if the author were forced to write them all out, and it reduces the probability of oversight or error on the part of the author. At other times, however, when the number of examples needed is fairly small or the rule is difficult to compose, the author can save time by writing out each needed variation.

E. Manipulation of Files, i.e., Directories, Curriculum Material, Performance Data, etc.

The facility for recording information in a log is of special significance in educational applications of computers, and was not typical of earlier systems not prepared specifically for computer instruction. Furthermore, the record of program status and of the occurrence of particular transactions are needed for on-line decisions.

The best tactic for record-keeping in a research-oriented system may be to write continually a log of everything which happens, and then let the researchers pick out what they need later. However, an operational system servicing students and teachers economically should log only the information certain to be needed and in a format suitable for quick and inexpensive summarization for use by learners and managers of the instruction.

Files are very important in a time-sharing system, and even more so in the instructional milieu. Generally a hierarchy of files should be available, the heavily-used files on disk storage and larger or backup files on tape or data cell since these modes are cheaper. Temporary files are necessary so that the terminal user can do "scratch" calculations. Some scheme of access should allow various read, write, read-only and write-only privileges to users, in accordance with the user's status.

III. GENERAL CONSIDERATIONS OF UNIVERSALITY

A. Universal Language by Established Standard

It is urgent that serious consideration be given to means for translating instructional materials and strategies from one institution and system to another. A standard or universal programming language is assumed to be the key.

Many people complain about proliferation of programming languages for instructional uses of computers, but few people are willing to let anyone else do something about it. Each project, each manufacturer, almost each individual user establishes preferences, working habits, etc., and would not like anything like standards imposed on him by someone else.

Attempts to impose a single major standard language (or a small number of languages) almost certainly will fail to establish translatability among institutions. Even if one could assemble enough support to produce a definition of a standard language, imposing this standard would be nearly impossible. Although the allocation of federal funds for curriculum development might be made conditional on that standard, funds will continue to come from a variety of sources, including the individual institutions who generate material for their own use.

Although strong forces will be encountered against standardization, one common language is not the important goal. Because of the great variety of purpose and process in instructional programming, a common language is less desirable than it might be in business or scientific programming.

If there is to be only one language which all users must share, then it must be some notation or set of conventions for describing computer-based learning exercises, or more generally, uses of computers and information processing in support of learning and instruction.

B. A Few Common Languages as Justified by Different Requirements

Different purposes require different languages. In the exploratory phases, the author (or research team) should have two or more procedure-oriented languages available, e.g., FORTRAN and SNOBOL, or PL/I and LISP 1.5. During latter stages of curriculum development, and in actual use with learners, the authors should have suitable procedures worked out and compiled (or coded in assembly language) for efficient operation, e.g., three alternate drill strategies, two modes for explanation and expositions, and a number of task-oriented environments. Perhaps one of the languages for exposition would look like COURSEWRITER or PLANIT, but it is not necessary and perhaps not desirable to begin there.

Achievement of standards with a different language for each identifiably different task is probably less likely than effecting a single language standard. All the problems of achieving agreement, acceptance, and widespread use are multiplied. However, the essence of "universality" is not standardization but translatability.

C. Automatic and "Manual" Translation Among Languages of Similar Purpose

New languages and systems will have greater capacity for translation of instruction programs from present programming languages in which they were implemented. Translatability is possible without imposing any restrictions on innovative ideas for language or strategy.

Investment in automatic translation from one language to another is an appealing concept; differences among learning exercises in regard to procedural aspects are disappearing. The major problem is the considerable cost of writing these translators, and maintaining them as various languages are changed.

In some cases automatic translation is not possible because of essential differences in hardware. One system may lack essestial clock or interrupt features. Functional differences occur in the input and output facilities, that is, the equipment used to display information to the learner and accept his responses.

The materials and strategy for one course were transferred to a new computer system by writing programs which automatically generated a set of new instructions for the second machine. The original course designers had conceived of the package of lessons in a general way so that the number of generators that had to be programmed was relatively small. Success with this approach to translation in part depends on the extent to which the curriculum designers separate data from procedure, i.e., content from strategy.

The current trend in translator writing systems (compiler-compilers, macro-generators, etc.) may provide for diversity within a common environment. The general functions of information processing, data structures, etc., are provided in a basic system. Each group of users still could extend and adapt the capabilities of the system to its particular task and for its convenience. The elementary functions or processes would remain a common standard, and translation could be made through an experienced programmer who reproduces the capabilities rather than the course.

Standardization, or more reasonably, "translatability" of computer-based learning exercises from one system and project to another requires attention to hardware as well as software. Important aspects of curriculum developed for a system rich in interactive capability (audio, graphic, etc.) may have to be dropped when moved to another system limited to typewriter input and output.

Clearly some useful work has been done with limited terminal capability. If one begins with the idea of adaptability to various computing systems and terminal devices (e.g., to most general-purpose time-sharing systems available in schools of engineering across the country), the problem appears solvable. A specific instance in the engineering area is the distribution of applications packages (STRESS,COGO, etc.).

For materials which are easily described by frames of information or test items along with simple branching decisions, the author's copy may provide the documentation for translation to another system and language. Easy-entry systems can be written for use with a family of similar language.

Perhaps the computer-based learning exercises which are a) most translatable, and b) most worthy of translation, are those which are viewed by prospective users as tools or open-ended exercises. A tool which an instructor can provide his students in situations of his choice and with his best advice will have a much broader audience than a programmed instruction exercise which decides all contextual considerations for the instructor. Such a tool is more readily translated to other computers and programming systems than the CAI materials with a closed approach.

Discussion of standardization and translatability is confused by failure to distinguish among different kinds of users and different levels of documentation. Automatic translation requires complete knowledge of two systems, and is extremely difficult or impossible if the intention to translate between two systems was not considered in the design of at least one of them. Manual translation by an experienced programmer requires documentation of one type; adoption by another user requires "documentation" of another type. Even with automatic translation of the basic code, the learning exercises may remain unused if the instructor/manager in charge has no convenient way to assess the content and methods of the exercise.

D. Communication and Documentation with a "Publication" Language

Documentation has two main functions, information transmission and work simplification. It transmits information to potential users concerning: (1) contents of instruction and (2) effective use and application of the program. It simplifies work by: (1) enabling the user to find actual or potential trouble spots; (2) assisting the user to eliminate problems which may arise, (3) simplifying revision; and (4) aiding reviewers.

At the same time one considers the means and costs of various kinds of translations of computer programs (whether automatic, manual, or a mixture), one must also consider means for informing the individual (professor, administrator, or even individual student) who must first decide whether to spend the resources for translation.

1. Among curriculum developers

Representation of a procedure statement for a curriculum expert not accustomed to computers requires an approach different from the standardized flow charting used by computer specialists.

Most languages are not suitable for describing the content and strategy of a learning exercise, and other means for documentation are rarely used by the authors. A significant portion of a two-million dollar budget for curriculum development and operations might easily be absorbed by the additional staff effort necessary to program interesting strategies with a language which is not suited to the task. Typically, nothing is left for documentation and distribution.

The separation of content (definition, facts, relations, etc.) from procedure (rules for review, error checking, etc.) makes documentation and translation a much easier job.

A communication medium for talking about instruction will promote design of more reasonable learning tasks, and serve also as a significant tool for advancing instruction research and strategies of curriculum development.

2. To reviewers and potential users

The difficult task of selecting a textbook or reference source for students is complicated when the author hides part of his material in a computer (along with some strategy for gradually revealing it to students). A potential user should not have to unscramble the cryptic computer program listing, or extract pieces paragraph-by-paragraph at a teletypewriter or CRT.

In most cases the essential information about a computer-based learning exercise can be absorbed without executing the program; careful study of proper documentation should provide all the information a potential user needs about the materials and logic.

Relevant information is obtained more efficiently through organized exploration of a description of the program than through reading individual records of student-machine interaction or through blind searching on-line at a student station for the eventualities for which the author has provided coding.

Actual experience with a computer-delivered exercise may be an important factor in understanding and evaluating an instructional unit, especially if certain knowledge and techniques are supposed to unfold or develop during the learning experience. An important component of some learning experiences is affective; that is, success depends on an impression or feeling of pleasure, satisfaction or possibly surprise. Negative experiences might also be identified by a curriculum reviewer in on-line experience more readily than in an author's statement of specifications.

3. To programmers

Within a number of applied research projects some means has been developed for curriculum designers to communicate with computer programmers: tables, problem formats, special notations, etc. These temporary measures have shaped the continuing evolution of programming languages for instructional systems, and could be formalized into a suitable "publication" language.

Humans can interpret by context many statements which automatic language processors find ambiguous, and this machine deficiency can be corrected only at considerable expense of programming and processing time, if at all. On the other hand, the computer programmer implementing a lesson should receive his instructions from the curriculum designer in some relatively constant notation which can be interpreted quickly and accurately.

Designers of computer-based learning exercises should be able to communicate directly with the computer. Whenever an intermediate programmer has to be called in, he should respond in a way which not only meets the immediate need but provides automatic (computer) handling of future requests, i.e., direct instructions from the subject expert to the machine.

E. Natural Versus Formal Language

The designer of a learning exercise should be able to instruct the computer system in a language natural to him and to his discipline, unconstrained by artificialities of computer notation and operation.

The formality of (most) computer languages is a good thing, requiring of the user increased attention to relevant details of his procedure. If one were able to speak to computers in completely unconstrained English, an impossible situation at least for a very long time, his directions would almost certainly lack the specificity required to determine prescriptions for assistance with self instruction automatically.

Formal language is desirable in instructional technology for a number of reasons, among them: tacit assumptions are excluded; ambiguity is reduced; description of procedure becomes more readable; and generalized procedures can be applied in other situations. In general, a formal language appropriately requires the user to reflect on what he instructs the machine to do.

Education and training in a discipline, in particular, the practical application of techniques to the presentation of self-instruction and other individualized learning materials, suffers because of inadequate communication with the English language. The community of users must use a relatively unambiguous language for discourse about purposes and procedures before it will benefit from a formal language for computer implementation.

IV. SYSTEM LIMITATIONS ON LANGUAGE

A. Hardware

Uses of auxiliary memory for updating formatted files of student records and making decisions in real time on the basis of certain aspects of the data require direct access to specific portions of the information. It is disappointing to find the disk and drum storage on conversational computing systems used in a tape-like fashion instead of as the direct-access file devices they really are.

When special symbols are required as in language, mathematics and the sciences, a printer-type terminal device will need special printing elements (as in the IBM selectric type ball), or an electronic display will need facility for user-defined characters to be generated (as on a CRT or plasma discharge panel with appropriate hardware attachments).

B. Software

When the subject expert and educational technologist become distracted from their real purposes by the peculiarities of current computer systems and programming languages, they should leave the computer for a time until the essential parameters of the learning situation are determined. If specifications for human tutoring are prepared as if for a more sophisticated computer system than is now available, techniques developed off the computer will more readily be adapted for computer implementation later.

A broadly conceived instruction system probably should begin with a general-purpose system and add facility for moving from the tutorial mode into other user sub-systems and returning when an exercise is completed. The author of a problem set may need to maintain contact with the student through some means of monitoring his work on a problem, and then bring him back to the tutorial mode because of elapsed time, number of problem attempts, or even an anticipated error which requires special attention.

Instructional systems should incorporate many programming capabilities which can be used by both author and student. In addition to simple computational aids, some lesson designers will want to provide an algebraic language, a text-processing language a model-building or simulation language, perhaps a specific system or model written for student use, or information organization and retrieval capability.

C. Communications

Each terminal device for communication between the computer and the user has physical and logical characteristics which determine the kinds of instructional techniques and/or computer system configurations for which it may be suitable. The suitability factors include facility for messages from users to computer (input); messages from computer to user (output); distance between computer and user; cost of communication link; cost and reliability of device.

The rate of message transmission from student to computer varies widely for different applications, but it averages out to about one keypress every two seconds, including the time for reading and thinking. The machine sends messages to each user in blocks, but the rate averaged out over all the time the student is reading or thinking is about two characters per second.

Communication costs usually are significant in servicing remote terminals in large numbers and/or at long distances. Since some devices require a voice-grade telephone channel but leave it 99% unused, some arrangement for multiplexing will allow many terminals to be serviced by a single line between the computer and the site of the cluster of terminals.

If a diagram or picture must be read from a video file associated with the central computer, much communication capacity will be required to get it out to the local terminal quickly. Alternatively, it can be sent slowly before it is needed, and then displayed as often as necessary from local storage associated with the terminal.

D. Summary of Cost Considerations

Other media than computers will continue to be less expensive for storage, presentation and testing; the economics of computer use are more favorable for practice and recitation exercises, where a greater degree of exchange between learner and data base is typical.

The response time and operating costs for any particular user depend in large measure on the priorities established for that kind of user when the system was designed and tuned.

Techniques for preparing curriculum files must be more powerful in the sense of fewer hours required of the subject expert to write and revise materials which achieve the objectives intended of the learning experience. Authors cannot often afford the luxury of individually shaping or tailoring each line of text in each frame for each kind of student.

It is today cheaper, and in some instances perhaps more convenient, to handle some desirable translator features manually with clerks and writing assistants. The next important step is careful development and evaluation of language features which adapt to the needs of authors and subject areas.

Conversational languages emphasize convenience, and sometimes require considerable additional cost in computer time during execution. The number of operations for interpretation of a symbolic program is always greater than for execution of a program already compiled into machine-level statements. Of course a user may be willing to pay more for execution if his results will be available immediately and without complication, along with quick diagnostics and opportunities for changes in the program at stopping points throughout.

V. DESIGN CONSIDERATIONS

Recent adventures in time-sharing warn of the inherent difficulties in such endeavors. Initial hardware investment is heavy; staff members must be very competent and well paid; results lag far behind effort invested in the project. A point too often overlooked by planners of new instructional projects is that time-sharing systems need large development resources, much larger than most researchers can afford.

A. Adaptability

Facility for definition of functions should be extended to provide for definition of a) character operations as well as numeric ones, and b) distributed operators which apply throughout one or more statement lines. The latter would allow for definition of new operations with convenient formats for specifying answer processing. More than one line should be permitted in the definitions, and the possibility of an operator being distributed among two or more variable names must be allowed in the parser.

One way to extend a language to handle additional applications is to provide linkage to other programs. No one language now available can handle the total variety of applications efficiently, and some useful subroutines may already be available in other languages on the same system. The major problems seem to be: 1) transferring data, 2) returning control to the calling program, and 3) leaving the user in control in spite of program or system errors.

The problems with extending a language through definition of new operators and statement types concern the internal representation of the language, simple rules for describing new features, and the ability to recognize operators distributed throughout a list of variables even on more than one line or program statement.

It is not obvious what the elements of programming should be. The basic statements and operations need to be elementary enough to permit building the variety of processes desired by programmers. However, high level commands should be assigned to frequently used routines constructed by programmers in a way that the syntax can be readily used by curriculum designers.

B. Economics

Variety and flexibility in programming capability of an instruction system are not necessarily incompatible with economical operations. Early decisions by system designers about specifically what is needed by users inappropriately limit the scope of applications.

New features defined within an interpretive language for execution as needed must be reinterpreted each time the function is used, and little economy of execution results. The ability to compile or assemble a routine, link it to the interpreter, and specify its execution in a statement form natural to the user will increase convenience while making certain information processing operations more economical to perform.

One way to accomplish some economic advantage is to reassemble the interpreter, adding the new statements, functions or operators to the language. This delays availability unless an informed system programmer is always at hand. Reassembly for one user also raises some questions of proliferation: Should he then have his own special version; do changes in the basic compiler take effect for everyone?

A recent addition to the tool kit of a system architectis microprogramming. The machine's instruction repertoire need not be wired-in; rather the processor is itself an interpreter of microprograms which are loaded in special memory, one for each instruction. For interactive and conversational uses the savings can be substantial in both time and speed.

Jobs without response-time constraints can run in the background to use any excess (idle) processor time. However, such jobs could destroy any benefit by slowing interactive responses and forcing greater overhead. Fixed memory can be allocated to the resident background jobs, but fine tuning is the tricky part.

C. Modularity

Language processors are usually designed in modules. Logical separation facilitates locating an error in the processor, introducing changes, and reprogramming the processor for use within another operating system.

It is not the modular concept but sensible programming which makes a difference. Separation into blocks of statements which have little if any interaction is only a way to encourage sensible programming.

D. Documentation

Encouraging uses of a system and language which has inadequate documentation is likely to lead to disappointment for users and frustration for those responsible for maintaining service. Errors or other considerations requiring modification are certain to arise, and the processors should be adequately described for maintenance purposes.

VI. INTERACTIVE MODE CONTRIBUTIONS TO LEARNER AND AUTHOR

A. Immediate and Responsive Reply

The essential contribution of interactive programming must involve responsiveness of the system, and this factor provides special benefits for the casual and infrequent user. He may be well advised, when unsure of the proper syntax, to try various likely ways until the interpreter accepts one and does what he intended. Better yet, the processor should tell him what form to use the first time an uninterpretable statement is entered, or refer him to the section of a reference manual which is likely to explain away his confusion.

If diagnostics, provided at the moment and backed up by references to readily available literature, can relieve the user of concern for the means to describe his procedure, he will give more attention to solving the problem. A shorter elapsed time between problem definition and solution, and the time savings attributable to continuous working sessions provide another bonus.

Much of the enthusiasm for conversational computing languages may relate to non-essential features; quick response and understandable diagnostics can be provided in batch systems.

B. Ease of Conducting a Dialogue and Learning the Rules

Interactive programming languages incorporate aids for program testing in a very natural way. The same statements with which stored programs are written can be used as direct commands to the computer to print the values of selected variables, assign new values to test other parts of the procedure, and resume execution with any line or segment of the program.

A rather deep search for the locus of a syntax error and some attempt to interpret the intention of the user in spite of ambiguity should help along the dialogue between user and machine. This requires a cleverly written processor with auxiliary memory and decision rules which generate special user assistance.

Naturalness is an important factor in using a language, and is achieved by internal consistency as much as by relation to native language. General conventions should apply throughout; the user should be able to predict a rule he hasn't been told yet, and one aspect of the notation should not interfere with his recollection of another.

The dialogue between user and program should be truly a dialogue. That is, there may be time when the computer should take the initiative, setting up stylized instructions and asking leading questions, and other times when the user takes over. However, throughout this exchange, each may interrupt the other to suggest a new arrangement.

C. Flexibility During the Working Session

Interactive mode of work should provide opportunity for sketching out an idea, testing parts of it, going back to fill in detail and make corrections, etc. The user should elect an on-line environment because it helps him conceptualize a procedure and solve a problem, not simply because it is an available way to enter a program into a computer.

Somehow a processor might recognize when a user is making temporary notes and when he wishes his work to be saved for future use. At least the user should be given a convenient notation for designating the expected permanence of current instructions, and a means to retrieve later something found to be of greater value than originally perceived.

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5. Evaluation of Computer-based Materials and Strategy: A Statement of Positions and Points of View*

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* These statements have been selected from published and unpublished literature to represent various points of view concerning evaluation of computer-based materials and strategy. Most have been shortened and some altered to convey the intent in a few lines within the context of a larger outline, and to point out similarities and differences with related positions.

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I. CONTRIBUTIONS OF THE COMPUTER

A. Contributions of the Computer to Learning

CAI reduces time for completion of a learning task.

CAI contributes to improved attention during learning in two ways. First, the interaction between the student and the CAI terminal focuses and maintains attention on the immediate learning task. Second, CAI systems have timing procedures that allow one to set maximum limits for response time.

[Hansen]

A discussion about individualizing instruction is like a discussion about predicting the weather. For present purposes we don't need a precise definition of "weather." We simply resort to our intuitions and recognize when these intuitions are violated by an example or a statement. We also recognize the difficulties of predicting the weather; the same is true of individualizing instruction.

Achieving individualization in instruction is an heroic task and may be impossible in many situations. Teachers can carry the burdens of individualized instruction only to a limited extent. However, the widespread use of computers for individualization of instruction seems practical and a feasible alternative.

[Suppes]

If the intent is to instruct students so that all will achieve a final level of competency which meets (or surpasses) a minimally acceptable performance criterion, with variation only in style, speed, or level of achievement, idiosyncrasy cannot be cultivated. Education then becomes what an industrial engineer might call mass production to narrow specifications with rigid quality control. Each pupil is free to go more or less rapidly exactly where he is told to go.

[Oettinger and Marks]

Maximum freedom is not necessarily a condition for individualization of instruction. Rather, some concepts of individualized instruction might include ends that the student himself defines as well as those ends which are stated behaviorally by somebody other than the student. [Becker]

B. Contributions of the Computer To the Solution of Educational Problems

1. Present and potential contributions

Computer-assisted instruction (CAI) is not the panacea for today's educational problems, and it would be a mistake today to introduce CAI on a massive scale. On the other hand, it also would be a grave mistake to reject CAI as a short-lived phenomenon or curiosity that should not be taken seriously until it has been proved. [Stolurow]

Many of the assessment, diagnostic, and remediation practices of school psychologists may be dramatically facilitated and expanded by computer-controlled interactive devices. If a significant proportion of the clinically-oriented school psychological procedures could be automated, then the current logistic limitations in terms of available professional personnel and the desired range of psychological practices could be resolved.

Computer-assisted instruction has two major implications for the field of school psychology. First, a direct impact on the range and types of psychological services in a school system could result in school psychology becoming anticipatory rather than reactive in style and practice. Second, the school psychologist will find CAI provides opportunities to pursue psychological research in a natural, pedagogical situation. [Hansen]

The evidence clearly indicates that CAI teaches at least as well as live teachers or other media, that there is a saving in time to learn, that students respond favorably to CAI, that the computer can be used to accomplish heretofore impossible versatility in branching and individualizing instruction, that true natural instructional dialogue is possible, and that the computer will virtually perform miracles in processing performance data. [Feldhusen a]

There are some things which CAI is able to do better than any other media:

1. Secure, store and process information about the student's performance prior to and/or during instruction to determine subsequent activities in the learning situation.
2. Store large amounts of information and make them available to the learner more rapidly than any other medium.
3. Provide programmed control of several media such as films, slides, TV, and demonstration equipment.
4. Give the author or teacher an extremely convenient technique for designing and developing a course of instruction.
5. Provide a dynamic interaction between student and instructional program not possible with most other media.

{Feldhusen b]

The student, the teacher, and the author can be economically provided with information in a form suitable to the needs of each. A CAI system eliminates the need for a large amount of separate data processing to make educational use of the data.

[Stolurow]

The potential of CAI to provide a major breakthrough in educational practice arises from the capabilities of a well-engineered CAI system (including instructional software) to provide an intensive level of individualization not possible before on a mass basis. The potential also arises from certain interactive and display capabilities of computers which possess unique promise for new forms of contact between learner and subject matter. [Bunderson]

To a limited extent a computer can substitute for a teacher in the learning process. When it does so it has the advantage of being in direct one-to-one contact, and though less flexible in response than a teacher, it is at least consistent [NCET]

Regarded as an educational resource, the computer itself can become an agent for innovation. Its capacity to present complex simulations and to perform complicated mathematical calculations at high speed offer new opportunities in many areas of the curriculum in schools and colleges. [NCET]

Possibly the greatest potential of computer-assisted instruction is its capability to provide the student with a facility for manipulating, redesigning, and rearranging the elements of a subject matter. [Glaser]

If statistical results obtained in the McComb program (CAI favors Negro and low-income groups regardless of teacher ability) can be replicated in other southern school districts, CAI drill-and-practice programs can make a significant difference in improving education in the South. [Prince]

There is no reason to believe that this new technology will necessarily dehumanize man. There are many things in this world that can be done better by machines than by human beings. The advent of the computer clearly points the way to major changes in education that will free the individual, both teacher and student, to interact in more human ways than ever before. [Holtzman]

Those opponents of technology who claim that it is dehumanizing to education are admitting their ignorance of what is actually occurring now. There is nothing more dehumanizing than to have a youngster who does not understand be subjected to having the rest of the class move along without him; or to have a youngster who wants to know, but who is not outgoing and is afraid to ask, be subjected to the torment of knowing that he is not aware. It is no more dehumanizing for an educator to use technology than it is for a surgeon to use the most modern of instruments for making incisions. [Pagen]

2. Comparison of the Computer with Other Media

The uniqueness of a CAI system resides in the computer which provides two significant capabilities: a large memory and flexible logic. While memory in a directly displayable form also is provided by a variety of other teaching aids, only the computer provides the detailed collated random-access memory of each student's responses to individual displays of instructional materials in a form that is directly useful for automatic processing. No other aid provides the computer's logical capability for organizing information to make it dependent upon the characteristics of the individual student. [Stolurow]

Computer-assisted instruction is distinct from other media in that it is a potential means for making instruction a truly individualized process through the use of a variety of media utilized to support a system of instruction. While programmed instruction and language laboratories appear to individualize instruction, they actually only take the first baby step in that direction by allowing the student to proceed at his own rate. Mass media approaches have provided an illusion of economy; hidden are costs of revision required to reach different segments of the total audience. With CAI we could individualize materials electronically rather than by hand. [Stolurow]

One of the advantages of the CAI system over other modes of instruction is the dynamic interchange it provides between student and instructional system. The system gives the student a set of conditions that are responsive to his performance. While this is also possible with programmed instruction using printed books, programmed instruction does not achieve the level of sophistication or provide the alternatives that are possible with a CAI system. [Stolurow]

Setting up a computer to teach children is just idiotic--a simple programmed workbook will do what the computer can do at one-tenth the cost. [Skinner]

Even when computer technology makes possible the acceptance of oral responses, the most effective supplement to the teacher's role in the learning of reading will probably still be the less costly devices such as the 'Language Master' and the 'Talking Page.' [NCET]

The practice of numerical skills is often related to a need to solve particular problems, and the most useful aid would be a checking device which could be a computer; but could be conveniently provided by a simple machine. [NCET]

Institutional needs which do not seem to require intensive individualization or unique computer capabilities (as exploited in simulation, gaming, or problem solving types of lessons mingled with a relatively small amount of tutorial CAI) can often be served adequately by some instructional medium other than CAI. [Bunderson]

Ideally, a teaching conversation with a computer can be extremely individualized, drawing heavily on the previous training, abilities, and performance of each student. A kind of complexity and individualization is possible that could be far greater than is obtainable either from programmed books or simply non-computer-based teaching machines. [Bork]

3. Limitations and other considerations

The growing pains of CAI are evidenced by:

1. Pretentious theoretical speculations.
2. Grandiose expectations of a major instructional role in schools.
3. Poor quality instructional programs and little or no evaluation.
4. Infatuation with computer hardware and systems.

[Feldhusen a]

The cost per student hour of instruction is hopelessly non-competitive with most in-school instruction, except probably some vocational and special or remedial education. However, technological developments will substantially reduce the cost of CAI, while personnel costs are rising. Also computer systems will be used by schools to perform functions other than instruction, and the bulk of system costs will be borne by these other functions (such as administrative data processing).

[Morgan]

It is important not to consider CAI as a learning process which involves the computer solely: the "system" could include, for example, teachers, printed material, and linear programmed texts. Many experimental developments of CAI have been ineffective because they have attempted to put the whole process on the computer rather than selecting those parts for which it is most applicable.

[NCET]

If there has been no clear-cut objective at which to aim, it is very difficult, if not impossible, to assess the success--or otherwise--of a project. When told that CAI is "better" than classroom teaching, one must ask the question, "How do you know?" Unfortunately, this question nearly always goes unanswered.
[McLaren]

The primary mechanism for moving the computer into the classroom is discovering discipline relevance; learning how to program and paying for computing services are only secondary. Suitable demonstration of curricular packages will enable the teacher to appreciate the relevance of particular algorithms to his subject area and gain facility with their use. Although in most high schools and in many colleges and universities resources have been sufficient for only token computer use, more realistic support will become available to incorporate these token ventures into the general education program. [Lykos]

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6. Research on Instruction and Learning

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*These statements have been selected from published and unpublished literature to represent various points of view about computer use in research on instruction and learning. Most have been shortened and some altered to convey the intent in a few lines within the context of a larger outline, and to point out similarities and differences with related positions.

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I. UNIQUE CONTRIBUTIONS OF THE COMPUTER

A. To Research on Learning and Teaching

1. Specific benefits

Research done on verbal learning (e.g., Fraze's work on the arrangement of parts of speech in a sentence, and Rothkopf's work on the placement of questions within text) leads us to believe that the computer can help considerably in facilitating replication, modification, and, in general, more rapid progress in experimentation. [CLUE Staff]

CAI should be used as a vehicle for new basic research on learning because of its unique capacity for controlled stimulus presentation, interaction with the learner, processing of responses, and storage and processing of performance data. CAI should be especially useful in research on verbal learning.
[Feldhusen b]

One specific advantage to be gained from a CAI system is the capability of doing research on teaching under controlled conditions and, in particular, under conditions which individualize the instruction. Another advantage is the capability of doing research on various modes of teaching with the ability to collect detailed records of student performance that permit evaluation of the effectiveness of the teaching procedures, as well as of the effectiveness of the material. [Stolurow]

Research conducted with a CAI system can offer the following benefits to an educational psychologist:

1. Reliable presentation of stimulus materials.
2. Convenient manipulation of one parameter while controlling others.
3. Rapid interpretation of data just collected.
4. Consistent replications.
5. Incidental administrative and computation uses.
6. Readily accumulated data from remote locations.
7. Research paradigms including complicated contingencies.
8. "Pin ball machine effect" to keep experimental subjects interested.

[Gilman]

2. Some warnings

Although CAI systems can handle a variety of psychological experiments, few studies will require this type of sophisticated equipment. Infatuation with or availability of hardware may be the cause of unnecessary automation with resulting problems and expense.

One study was the only completed product of a six-month project with a half million dollar yearly research budget. The study has since been replicated with a small solid state teaching machine (called a Didactor) that can be programmed to do many of the research paradigms of a large CAI system. The total budget for the replication was less than five hundred dollars.

[Gilman]

Although CAI, with its versatility, can be an asset to the educational psychologist conducting research on learning, the present state-of-the-art will cause some problems. The researcher should consider CAI a technique to assist him in learning about behavior, rather than a facility he must somehow put to use.

[Gilman]

Unfortunately, current learning theories do not enable us to match the functioning of the human mind against the functioning of the computer. No unified theory exists: one--that of "complex stimulus-response chains"--seems to explain some processes, another--"cognitive structuring of a field"--other learning processes.
[NCET]

Optimization is pointless and even of negative effect if the measures implied by the model are not relevant to the educational goals. Successful application of optimization assumes that a psychologist can represent accurately the state of knowledge of a student at a given time and that instruction will influence the transition from a faulty state of knowledge to a more desirable one.

Some models of learning are too simple to be helpful. The corresponding procedures for optimization in such models do not take into account important factors of motivation, context, previous learning, or learning style. Other prescriptions for learning, some of which are called models, do not make sufficiently specific reference to the initial or interim observable behavior of the learner and, therefore, are not useful for managing instruction.
[CLUE Staff]

Research into learning processes is as important as any research into the actual application of computers. A corollary of this is that it is impossible at this point in time to state categorically the ultimate role of computers in the learning process. [NCET]

B. Unique Contributions of the Computer To the Development of a Theory of Instruction

The field of instructional use of computers is still in its infancy, and the facilities and materials are not yet adequate for development of anything so general as instruction theory. So far most of the work has been concerned with developing the technology. [CLUE staff]

Probably the major problem with CAI today is that its current level is mistaken for its potential level. In effect, CAI makes our meager knowledge of teaching patently obvious.

Our most pressing problem is the lack of an empirically validated theory of teaching, and in fact we even lack a useful set of empirically validated principles of instruction that could form the basis for a theory of teaching... Hence, one of the most vital functions of CAI is, potentially, the development of an empirically-based theory of teaching designed to meet the requirements of individual learners. [Stolurow]

CAI developers ought to leave to others the development of theories of instruction. Instead, they should study and glean what they can from established theories of instruction .

[Feldhusen b]

Probably, the most significant contribution of CAI has been an indirect one. As researchers tried to program material for the computer, it soon became apparent that psychological theories of learning were not entirely adequate, and what was required was a theory of instruction. [Molnar]

CAI has grown rapidly into a dynamic and promising field for educational research and applied instruction. While the empirical research per se is often of poor quality and poorly reported, the development of systems and instructional theories is proceeding with great promise. [Feldhusen a]

CAI researchers should feel free to work within or without the constraints of instructional theory. For some, theory development serves the heuristic purpose of alerting the researcher to all relevant aspects and of providing integration. But adherence to a single theory also blinds the researcher to alternative views. Thus, some people will thrive by being eclectic and exploratory. [Feldhusen b]

Even if it were possible, a theory of CAI would be harmful in that it would blind the CAI developer-researcher to the broader range of instructional resources which should be tapped in developing a program of instruction. In a sense, this is the sin which PI researchers and developers have been committing. They have been blind to alternative forms or media for instruction. [Feldhusen b]

Another possible advantage of the learner-controlled statistics course is the discovery of routes through a given subject matter from the student's point of view. Another intriguing avenue which opens in the learner-controlled statistics course is the provision for learning either by an inductive or deductive mode of reasoning. [Grubb]

II. GUIDELINES FOR FUTURE RESEARCH

A. Role of Individual Learner Differences

Instructional systems need to be developed to respond to individual differences in an efficient manner. Guidelines for doing this are not yet established. This goal is not being served by other more established procedures; consequently, this should be the main purpose of CAI. [Stolurow]

There is little evidence from research to support the view that individualization of instruction is the sine qua non of learning. Widespread practice in schools at all levels indicates that much, but not all, instruction can be carried forward in groups. [Feldhusen b]

Research on the interaction of individual differences with various methods of instruction has produced few significant results. This may be due to poor selection or measurement, weak methods, and/or failure to secure appropriate assessments of ongoing performance. Continued research efforts should be made to explore the claim to individualization of instruction. [Feldhusen b]

The concern about individualization has been mostly lip service. It has not been defined operationally; present attempts at implementing it are not complete enough and have been squeezed back by institutional pressures; and it is also extremely difficult to accomplish. Many current experimental computer-instruction programs give only the illusion of individual tailoring. [Oettinger and Marks)

The most pressing need in education is the individualization of instruction. Education dedicated to this end not only maximizes individual competence but provides every individual with a sense of pride and uniqueness and a feeling that he can contribute as a fullfledged member of society. When the individualization of education is taken seriously, it is difficult to think in terms of such categories as "the very talented," "the disadvantaged," "the handicapped," and so forth. Rather one thinks in terms of the capabilities of each individual and how to provide an optimal educational environment for that individual. [Glaser]

Individualized instruction requires instructional decisions relevant to each student. The differential decision-making function in individualized instruction is a central issue, and these decisions require a great deal of information about the individual student. [Cooley and Glaser]

Considerations for recognizing individual differences include: rate of student progress, selection of instructional objectives, and student control of program branching. Only the computer provided a reasonable means to keep track of everyone, match resources with individuals, and schedule people and materials at the right time and place in an entire educational institution. [Holtzman]

The discovery of the types of interactions between individual differences and learning variables is perhaps one of the toughest problems the psychologist will have to face. The kinds of individual differences referred to here are differences which develop from the long-term history of the learner: aptitudes, learning styles, personality characteristics influencing learning, and prior training and knowledge. [Glaser]

B. General Guidelines for R & D

Research on learning with CAI must continually address itself to the criteria of success. One bad way of avoiding the criteria problem is to use available test instruments which inadequately approximate the goals of the program. The CAI programmer must specify the intended learning outcomes and develop suitable criteria behavior measures. [Feldhusen b]

Applied research should focus on known principles of learning and on capabilities specifically related to computers. For example, research on learning suggests that specific informational feedback to the learner about the adequacy of his knowledge or performance increases the amount learned and liked by the student. Thus, a wide variety of tests of this proposition should be devised in the CAI setting to verify its application there. Researchers earlier found that the report of correct answers in a programmed instruction format had little facilitating effect on learning, perhaps because initial performance was so highly prompted that there was little possibility of error in performance or need for correction.
[Feldhusen b]

Research and evaluation functions related to CAI must be clearly defined at two levels: 1) during the development of CAI materials (guidelines by Scriven, Markle, DAVI and Popham are relevant) and 2) after the CAI material has been developed and is ready for field testing and use in CAI research (Campbell-Stanley guidelines are relevant). Much of the research has used the limited experimental-control group design with small numbers of subjects, poor criterion tests, and brief treatments.
[Feldhusen b]

A national program in the UK should apply some of the known concepts of learning theory and techniques of computer programming to the task of preparing a variety of CAI teaching programs in different subjects.

However, because a "learning system's model" (or even a teaching one!) has not been identified, it is unwise to base any national program solely on the results of basic research into learning theory or behavioral patterns. Rather, research into learning theory should proceed simultaneously with (but not necessarily as part of) the development of national programs. [McLaren]

CAI is now and will for some time remain in a research and development (R&D) status. The major areas of need include the development of inexpensive yet enriched student terminal devices, author and student languages which better exploit the computer's unique capabilities, and the development of instructional design procedures and facilities which will yield effective and well justified instructional programs. A more general yet more basic problem is that of developing educational environments which are compatible with individualization. [Bunderson]

CAI may never reach its potential unless continuous progress programs are developed on a wide scale. These may involve media of all sorts in addition to computers, and may be conducted under new management models for instruction which emphasize individualization. [Bunderson]

Perhaps ten years ago the promise of computer control and analysis gave us an illusion of having greater control over experimental design. It simply has not worked out that the experimentation takes care of itself. Some research studies are being done on the computer systems simply because the systems are available and must be justified. The monster with its monthly rental requires new research money all the time to maintain it. Administrators should look to alternate facilities both for conducting the research wherever possible and for administering the instructional materials. [CLUE Staff]

Computer systems as they are designed today do not provide a rich enough environment for some contributors to development of automated learning exercises. Therefore, some work should leave the computer for a time, perhaps the next five years, in order to explore strategies not necessarily dependent on computer processing of natural language. For example, one might set up learning environments and problem solving situations in which he studied the behavior of a student while solving problems and acquiring concepts. Although the computer might be used as a tool in modeling the student's behavior, communication between the environment (eventually to be automated) and the student would be carried on by humans. Critics of present uses of computers for instruction want more effort expended on a more fundamental purpose; namely, the better understanding of student learning and self instruction in semi-automated environments. [Zinn a]

Expensive, on-line systems will continue to be used for research on learning and teaching and for development of self-instructional programs. Computers and communications are especially important because the training devices can be located in public school classrooms, business offices, and engineering shops or laboratories, through which an information processing system can instruct, answer questions, deliver tests of understanding, record data, and test hypotheses regarding instruction and learning with great detail and over long periods of time. The capability to introduce experimental control into situations satisfying the real demands of education and training will reduce the present discrepancies between contrived laboratory situations and actual applications of learning principles in training and education. [Zinn b]

Before substantial amounts of new CAI research are undertaken, some major systems problems should be solved. First, an inexpensive CRT should be perfected to replace the typed message. Second, the student interface should be developed as an efficient and pleasant carrel which affords access to several media. Third, time sharing service and terminals should be abundantly available to avoid artificial constraints on instruction. Fourth, one set of programming languages should be developed for several modes of instruction such as didactic, inquiry, and computation, and for the author mode. Fifth, some lengthy courses (3-6 credits) should be developed to serve as vehicles of research and as models of CAI potential.

With suitable equipment, systems, and instructional software, CAI research can then come on hard and hopefully begin to produce significant results.

[Feldhusen b]

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7. Documentation and Distribution of Information and Learning Materials: A Statement of Positions and Points of View*

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* These statements have been selected from published and unpublished literature to represent various points of view concerning dissemination of useful information about computer-based learning. Most have been shortened and some altered to convey the intent in a few lines within the context of a larger outline, and to point out similarities and differences with related positions.

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I. ASSESSMENT OF CURRENT DISSEMINATION EFFORTS

A. Information Levels and Needs: Recognize differences among users.

Information may be described in terms of the level of confidence one has in it. At the highest level are results of investigations that have been published in refereed journals or by publishers with editors accepted in the field of the investigation. The intermediate level includes "published" technical reports, papers "read" at professional meetings, and preliminary results of studies underway transmitted among friends at professional meetings or on visits. The lowest level is only a hunch, or educated guess, which acquires confidence almost entirely from the respect tendered the guesser.

The higher the confidence or credibility of information, the longer the delay in public announcement. Thus, the information in which one places the greatest confidence (in technical disciplines of rapid change) is most likely to have been superseded by the time it is known, although its successor is not yet available. [Merrifield & Mood]

Three varieties of university-based researchers may be considered: the teacher-scholar, the professional researcher, and the student. The research interests and information needs of teacher-scholars tend to be either specific, with a component of immediacy, or vague, with a kind of timeliness about them. Those of the professional researcher tend to be rather well-structured and well-scheduled, with a strong component of interest in methodology per se. The research interests of the student tend to be vague with a yearning for a specific problem evidenced by concern for both methodology and the inclinations of his mentor. [Merrifield & Mood]

The professional researcher's need for high-confidence information is immediate. Whether his frontier is in depth or near the periphery of his field, the presuppositions on which his study rests are likely to be based on fairly recent research by himself or others. The need for early confirmation or rejection of these assumed foundations is apparent, if the research program is to be an efficient one. [Brown, Miller & Keenan]

B. Opinion About Information Services: They are quite variable.

Information and consulting resources which are currently accessible to the researcher and program developer fall into four discernible categories: 1) private "not-for-profit," partly subsidized organizations (such as Entelek, initially); 2) profit-making commercial organizations (e.g., ICAI, CAIS,ETC); 3) university and government-supported services (such as ERIC Clearinghouse at Stanford and the Instructional Media Laboratory at the University of Wisconsin in Milwaukee); 4) individual, specially-funded studies (e.g., "Education in the 70's", RAND study on Computers in Higher Education, and Project CLUE). [CLUE Staff]

Results from a questionnaire sent to several project directors throughout the country revealed that some groups either were not aware of or had not used certain of these resource categories. Findings also tended to confirm general opinions expressed informally by persons engaged in CAI activities. 1) university and government-supported clearinghouses were given the most favorable ratings. 2) private "not-for-profit," partly subsidized organizations, and particularly the profit-making commercial services, were criticized for being too expensive, material not current enough, inaccurate abstracting, too commercial lacking professional review. [CLUE Staff]

The private sector of the economy has demonstrated its ability to respond quickly to needs of the nation's educational institutions. Only the private sector has the institutionalized method-marketing for getting research translated into practice.

Non-profit educational institutions should be wary of trying to use tax-payer funds to organize non-profit service institutions from which purchases can be made. Frequently, their efforts are based upon the almost invariably erroneous assumption that a non-profit organization subsidized with public funds will furnish better service cheaper than a profit-oriented organization. Such institutions should be established only when it is certain that the private sector will not meet a felt need. This is not the case in the field of computer-assisted instruction, since private companies already in being and those likely to be formed in the near future will provide a wide proliferation of services for CAI. [Kyle]

C. Role of Publishers and Manufacturers

At the present, there is little the publishers can market, although a great deal can be poured into research and development. To what end, though, is difficult to envision because of the lack of standardization of equipment. Publishers could develop supplemental "workbooks" and the like to accompany learning exercises on a computer system if they were involved in some way with that kind of computer activity, e.g., wished to put in R&D money. [J. Wilson]

The publisher's responsibility for information about pilot projects will no doubt remain in its traditional form: publication of monographs, edited collections of readings from journals, technical reports and unpublished documents, and books by individual authors describing in depth their experimental work.

The major responsibility for dissemination of fully developed courses even though developed by computer will probably remain with major publishing houses. Editorial and sales functions, while ill-designed at present for CAI, will probably be easily adapted to their new roles. The major problem facing publishers is the implementation of a given program on a variety of hardware systems. Many new techniques and a new channel of cooperation between publishers and hardware manufacturers must be developed before the production and distribution problem can be solved. [H. A. Wilson]

It is impossible for manufacturers to anticipate all needs of educational users, who in turn cannot specify all requirements until they become involved. An interactive developmental cycle is thus implied. Mutual trust and cooperation between educators and manufacturers is complicated by the educator's open environment and tradition of free exchange of scientific data, contrasted to the manufacturer's concern for protecting proprietary information, or releasing possible defective products too early. The new user's group for IBM instructional systems should prove an important voice in bringing evolutionary development in CAI hardware, at least for one vendor. [Bunderson]

D. Specific Concerns: Incentives, reviews and copyright protection

1. Little incentive for documentation, distribution, and revision.

One reason authors are not interested in documenting computer-based exercises is the lack of standardization in computer systems; few others could use the product. More important is the lack of institutional rewards (academic and economic) for such material. In spite of assurances at some schools that teaching and especially innovative curriculum development will be rewarded as much as research, academic administrators continue to ignore instructional material in determining promotions and salary increases. [Zinn]

Many professors initially enthusiastic about computer-based curriculum have later been discouraged by the tedium of coding, testing, and revising them. On some occasions needed revisions have not been implemented because of the cost and elapsed time, as well as limitations in the system and language. [Zinn]

The high costs and low incentives encouraged by the original author of curriculum materials are even more serious factors for potential users who may wish to adapt the computer-based exercise somewhat for their own students and educational objectives. Documentation of computer programs is unavailable, and incentives for modification are small if the credit remains with the originator. The commercial system knows how to encourage an individual to prepare a useful second edition of someone else's textbook. [Zinn]

2. Need for information, review and evaluation

Many people are not aware of what others are doing in a related field. There is an appalling lack of information about similar work, not only at the other end of the United States, but often in the same, or neighbouring, state and even in one case on the same campus, indeed with the same department of the same campus. [McLaren]

Practically all the teaching material prepared for computer use has been done in such a way that one cannot readily take it over into a new situation. The project which produces only programs is failing to fulfill its obligations to the world as a whole. More attention should be given to documenting such material so that others may decide if they wish to use it. [Bork]

Results of a survey of researchers interested in educational technology revealed that computers stand out as one of three media (among eight possible choices) most in need of coverage, and priorities are for information about research/evaluation activities, use/cost factors, management of instruction, technology (hardware), and content of instruction, in that order. [Paisley]

Unpublished literature dominates the communication among researchers and developers: conference papers, papers circulated only among the "in" group, reports "published" by research and development centers, and military and industrial documents. The gain in speed of communication among researchers accomplished by using unpublished materials carries two substantial hazards: 1) material is not evaluated, and 2) communication is haphazard. [Feldhusen]

3. Pending copyright considerations

Authors of CAI material have generally found it either impossible or impractical to take advantage of property rights in their products; moreover, the legal status of an easily-copied program is not entirely clear. [Sharpe]

The lack of an adequate and meaningful revision of the U.S. copyright law is an important factor impeding development and distribution efforts. The present copyright law is 60 years old, and, though amended several times, it does not reflect the controls needed to protect the authors and publishers developing and adapting materials for contemporary forms of communications media. [CLUE Staff]

A survey of professors using the computer for classroom instruction at he University of Michigan indicates that sample materials and research findings are disseminated primarily through papers read at professional meetings and informally circulated among colleagues. Several professors expressed willingness to develop and document experimental computer-based learning exercises if professional journals and publishers showed more interest in disseminating them. Other difficulties cited were lack of time, lack of funds to hire assistants, and lack of interest in showing unevaluated materials to others. [CLUE Staff]

Authors of new-type instructional materials for computer systems that display acceptable originality will receive protection in any ultimate revision of the copyright laws. The greatest difficulties encountered in developing desirable revisions of the laws relate to the ease with which published materials, including copyrighted materials, can be duplicated by employing recently developed technological devices. This duplication may be carried out in a variety of ways, including, as a possibility, duplication in the memory unit of a computer. **[Newsom]**

A proposed copyright law would restrict computer storage and processing of texts, although reasonable ways exist to provide suitable payment to the owners of texts stored in a computer whether it produces hard copy or only an electronic display. The prospect is that some publishers, whether through lack of attention to a request or unbased fears about new technology, could legally restrict the availability of knowledge and its manipulation for further uses. **[Zinn]**

II. GUIDELINES FOR BROADENING THE BASE OF USERS OF LEARNING MATERIALS

A. Formalize and Standardize Procedures of Journal Dissemination and Review

Periodic critical review is needed from various points of view. The occasional consideration in the Review of Educational Research, the Annual Review of Information Science and Technology, Computing Surveys, and other review publications should be made more regular and comprehensive. Perhaps a special review of computers in education is needed, from the point of view of educational technology.

A few journals are publishing papers which contribute to the body of research knowledge, techniques and successful applications: American Educational Research Journal, Journal of Educational Research, Educational Technology, and Communications of the Association for Computing Machinery.

Dissemination and review of computer-based learning exercises should become associated with professional societies and discipline grouping. For example, the American Journal of Physics publishes refereed notes on instructional use of computers. [CLUE Staff]

B. Provide Better Incentives to the Author: Academic credit, protection reimbursement

It is most unlikely that the overall reward structure of the university community can be altered so dramatically that faculty members will begin to produce large amounts of CAI material with no further incentives. Administrators must lower the costs and/or increase the rewards to a professor for preparing learning materials. One means is to give CAI material greater generality and longevity. Another is to provide explicit and direct rewards to the author.

[Sharpe]

Some sort of academic credit should be extended to authors for producing innovative and useful computer-based learning materials. This could be done by establishing regular reviewing and evaluating procedures in professional journals. Since contributions to his academic discipline are the chief determiners of a professional researcher's merit, the reviewing should be incorporated in discipline-oriented professional journals rather than education journals. [CLUE Staff]

Once the complexities of the problem have been resolved in the form of a suitable copyright law, the scholar, using the computer as a tool, will benefit the more, in keeping with the time-honored American concept of favoring the public right of access over the author's monopoly. The scholar involved with the computer as author, along with his publisher, might appear to lose some of his control, but will ultimately benefit professionally and even financially from the broader use of his material as it is translated into media other than the printed word. [McCartan]

Providing economic motivation to the potential author of computer-based learning materials has been unsuccessful. A whole industry is geared to encouraging writing of books, but no corresponding means exists to reward the writing of a CAI course despite the fact that, like a good book, a good instructional program can be used by others than its author. A mechanism is needed for collecting from the user--as from the performer of a musical composition--fees for use of original materials. [Gordon]

It is a relatively simple matter to modify a computer's operating system to account for the use of a program or set of data. Moreover, the originator can arrange to have his program or data used by others but not copied or examined by them. Thereby instructional programs and data bases can be offered for fees, with property rights reasonably well protected. [Sharpe]

Many time-sharing services have implemented royalty schemes. The author's fee is related in some simple manner to the charge levied by the computer service while the program or data are being used. The computer service collects the total amount, paying the author upon collection.

The author can take on the billing function himself, writing into each program instructions to record relevant information about its use in a file accessible only by the author. Users can then be charged in any manner acceptable to them. [Sharpe]

C. Expand the Role for Publishers, Manufacturers and Information Services

Greater effort must be made to improve the quality and quantity of resources available to the researcher from the clearinghouses and publishers, particularly from the "not-for-profit" and commercial services. Possible activities to meet this need include: a conference to discuss ways to evaluate, document, and distribute computer-based learning materials and literature describing research efforts; and establishment of a pilot operation to demonstrate how an interuniversity "library" of such materials and literature might operate. [CLUE Staff]

The R&D required to implement CAI and individualization widely and successfully presents a task which requires close cooperation between university laboratories and industry, in both hardware and software development. Relationships with publishers in regard to instructional software will become more and more necessary to provide dissemination and standardization. [Bunderson]

Along with the additional capability of the computer to add new dimensions to traditional instructional materials comes an increased degree of complexity for the publisher. The skills required to produce good CAI materials do not necessarily reside within the publisher's current editorial and publication staff. The flexibility and dynamic aspects of this new medium bring with them additional management and logistic considerations that are not now within the traditional role of the publisher: 1) programming skills as well as maintenance and a documentation scheme for the software; and 2) standards for interchange of course material. Even with these additions to the publisher's role, his major responsibility of providing appropriate educational materials remains paramount.

The speculation that hardware manufacturers will significantly influence what is taught in the classroom seems to be ill-founded. The publisher, with the author, will continue his traditional role of providing the school with a portfolio of educationally sound offerings and the determination of educational value will reside primarily with the educator and the publisher. [Bacon]

D. Guidelines for Documentation of Learning Materials: Excerpts from one set of recommendations

Each group of users can benefit if it adapts and evaluates the materials of others, and has its own materials tried on other systems. Translation of materials and instructional strategies can be facilitated by a common notation and other conventions for documentation.

In most cases the essential information about a computer-based learning exercise can be derived without executing the program; careful study of proper documentation should provide all information about the materials and logic short of operating system characteristics. It is often more efficient to obtain relevant information through organized exploration of the program description than through reading individual records of student-machine interaction or through blind searching on-line at a student station for the eventualities for which the author has provided coding. However, a number of approaches are mentioned below:

Special notations: A variety of information processing functions are placed under author control in languages for programming computer-based learning exercises. Any general notation should be convenient for representing all of these aspects. Although it is possible to represent teaching logics or training patterns in existing flow chart notations, such diagramming is less convenient than it might be. Some simple instruction processes require greater volume of charting than should be necessary for author purposes; some standard symbols have little mnemonic value in this particular application of computers. Some functions unique to educational and interactive applications require special symbols if lengthy explanations are to be avoided.

Content summary: The usual way to describe a textbook chapter or programmed unit is to provide a brief listing of what it "covers", e.g., McDougal's laws. This general information can be useful, especially to subject experts who have much experience with the textbooks and conventional procedures, for presentation in a particular area. However, if a decision to use certain materials is being made carefully, much more detail is needed. First, it should be determined what requisite skills and knowledge are assumed of the student when he begins the learning exercise. Secondly, the central concern is what the student is actually able to do differently at the end of instruction. Third, suggestions are needed for how the materials are best used to achieve the goals, and how secondary goals not explicitly sought by the author may be affected.

Records of interaction: Listings of the interaction or conversation a "typical" student may have with a computer program have been published to convey information about instructional programs. A number of shortcomings are apparent: one is often left wondering what would have happened had the student said something else. More specifically, one cannot be sure whether an apparently appropriate computer response was provided by chance or actually resulted from a recognition of the student answer or request. Finally, one would have to read a large number of such transcripts in order to gain very much information about the full extent of content and logic in the instructional unit. However, a record of interaction can present a realistic sample of how the program actually does perform, and it emphasizes for the reader the continuity of conversation which might be achieved with an individual student.

To take full advantage of this technique, footnotes or marginal remarks should be used throughout to indicate alternative treatment that might have been given this student had his response been otherwise. The annotator should indicate what part of a response was recognized and processed by the computer. More than one transcript of interaction with a program should be presented, and each should be selected to represent another type of student or learning situation.

If the single purpose of documentation is to communicate information about one's material and logic, transcripts could be simulated from a detailed flow chart of the interaction. That is, the samples would be designed to best represent interactions for which the author has provided coding.

On-line experience: Actual experience with a computer-delivered exercise may be an important contribution to understanding and evaluating an instructional unit, especially if certain knowledge and techniques are supposed to unfold or develop during the learning experience. An important component of some learning experiences is affective, i.e., success depends on an impression or feeling of pleasure, satisfaction or possibly surprise. Negative experiences might also be identified in on-line experience more readily than in a statement of specifications. For example, the delay in response time is a complicated function of the student's thinking time and the magnitude of the job he believes he has given the computer. Information about the length of time students must wait, e.g., average reply time of 2.6 seconds with under 10% exceeding 5.0 seconds, is not as impressive as actually having to wait various periods of time, including some long delays. Problems with keyboard input perhaps have affective components not readily described, such as the frustration of trying to represent a mathematical equation or a diagram in a manner which can be interpreted through a keyboard connected to the computer.

In general, on-line experience is not a practical way to obtain information about computer-based learning exercises; it requires more time of the reviewer, transportability of materials, etc. However, first-hand use provides a context within which the evaluator can then place vicarious experiences obtained through the other summary techniques described above. [Zinn]

E. New Organizational Arrangements: Collection, distribution and exchange

1. Standardized curricula

A factor that may overshadow technological considerations as a determinant of software cost is the evolution of institutional arrangements for software production and distribution. As long as CAI material is to be produced by individual professors for their individual courses at each institution, software cost will represent a high proportion of the total system cost of CAI; each lesson will be used by only a relatively small number of students. If it becomes possible to standardize some aspects of higher education curricula to the extent that CAI material can be used by numerous institutions, then the average cost of software per student per year can be substantially reduced. [Barro]

Major institutional changes may be needed if CAI teaching is to take over the major burden of instruction in a subject. The professor can no longer be the proprietor of "his" course; computer-based instruction might become a service provided by an academic department, taken by students on a "contract" basis at their convenience, or prescribed for completion at or before some specified point in the curriculum. A new style of academic organization would probably be required to administer such forms of instruction. [Barro]

New organizational arrangements are needed to stimulate and facilitate software production. A number of possibilities have been discussed, ranging from procedures similar to those in book publishing, whereby financial incentives are provided to authors of instructional programs, to development of independent organizations specifically for production of instructional software. The future shape of the "instructional software industry" may have a significant effect on software cost per student hour. [Barro]

2. Centralization of Resources and Training

In order to diffuse common practices for documentation, programming procedures, instructional strategies, etc., some kind of professional library and perhaps a central resource for development of computer-based learning exercises could be established. If authors from individual institutions were encouraged to come to one or a small number of sites to develop materials in a particular discipline area, the facilities and personnel there would encourage certain accepted techniques for implementation and documentation of learning exercises.

Independent research efforts would continue to explore new techniques which, when validated, would feed into the regional or national centers. Some arrangement such as this is needed to focus attention on those languages and techniques which prove successful for large numbers of users in various discipline areas. [CLUE Staff]

Carefully planned dissemination projects could facilitate the distribution of instructional materials and strategies beyond the individual projects and computer systems with which they were developed. Probably organized within disciplines, such activity would include a combination of conferences, working meetings and a newsletter or other publication to promote translatability of learning exercises from one language and system to another. [Zinn]

3. Computerized networks

The potential utility of computerized networks seems to be most significant for the professional researcher requiring faster access to information in which he has confidence then is presently possible through refereed journals. The result of such prompt dissemination of recent research findings or ongoing experiments might be more opportunity for fruitful discussion. [Merrifield]

Although access problems are capable of solution by a computerized network, the value of immediacy to all but the professional researcher seems relatively unsubstantiated. [Merrifield & Mood]

The simultaneity offered by an inter-institutional computerized network might remove the often artificial controls that limit the generality of research, while at the same time providing the corroboration of experts that is now approximated by the replication of studies. [Merrifield & Mood]

Immediate dissemination of refereed and edited manuscripts would be very helpful to the professional researcher, and perhaps necessary to the continued acceleration of research. Any early abstracting service coupled with computerized dissemination would be worthwhile. No doubt such dissemination would have to be conditioned on a royalty scheme or some kind of guarantee of economic and professional credit.

Further, the professional researcher could be presented, automatically, with information, perhaps abstracted, for which his research area is only a secondary descriptor. New fields grow from unions of fringe areas, as has been frequently demonstrated. The need for this kind of information is perhaps not so urgent as to warrant its entry on an electronic channel; the function of a computerized network here is not so much speedy dissemination as comprehensive culling. The activities of ERIC along this line are promising. [Merrifield & Mood]

III. A VIEW OF THE FUTURE

The industry for producing, marketing and distributing CAI material to colleges and universities will develop much as the textbook industry has.

College faculty members, working individually or in groups, will produce instructional programs. The initial impetus and the testing-ground for these programs will be provided by the faculty members' courses. Few authors will invest significant amounts of time and money at the risk of not having their materials accepted for use, so it is expected that development costs will for the most part be charged to the university.

Compensation typically will be on a royalty basis, and an author will want to work with a firm that can market his material efficiently. Risk-sharing and compensation probably will differ little from the arrangements currently used for textbooks.

Traditional publishers will take on the editorial and marketing function. Procurement editors can be trained to solicit marketable CAI material. It will cost less to add CAI products to the line of educational materials already handled by the publishers than to provide an entirely new set of channels for soliciting potential producers, procuring markets, and distributing materials.

Material will be distributed on commercial time-shared services. Some services will provide low-cost storage, some low-cost computing, and others low cost input and output. The firm which solicits, revises, and markets material does not need also to provide the computer services on which the material is made available. Material will be offered at premium rates, with the premium split between the publisher and the author.

Terminal equipment often will be provided by the college or university; however, the students will be expected to bear most (if not all) of the costs of using CAI materials. For example, a coin slot on terminal equipment could be used in much the same way that coin-operated typewriters (usually in the library) are used by students today. A coin deposited by a student would send a special bit pattern over the line. The computer service would then increase the student's account balance, and he could use the system as long as his balance remained positive.

CAI materials will have to survive competition with textbooks. The student will have the option to economize on computer use or to avoid the costly machine entirely by depending on alternate materials. The industry for CAI material will develop only to the extent that buyers are convinced of real advantages over conventional published material.

Some CAI materials will compete with instructors as well as printed material. Traditionally, additional instruction is provided free of extra cost, thus encouraging rather substantial use by students. If the same strategy were adopted towards costing use of equivalent CAI material, peers and administrators would have to determine the relative worth of CAI vis-a-vis traditional instruction. [Sharpe]

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VOLUME II - APPENDIX A

CONDUCT OF STUDY: PROCEDURE, COORDINATION, DISSEMINATION

An abbreviated description of the project is given here to inform the interested reader about the procedures used to collect and interpret information, the coordination with other review projects, and the dissemination of tentative findings and supporting information during the project itself.

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Project CLUE

December 1970

Brief History of the Project

A framework for discussion and recommendation was extracted from primary sources during the early months of Project CLUE (January through March, 1969). Staff members searched for current and relevant materials in order to interpret what was being done, what had been planned, and what was judged to be most needed and important. The survey was aided by suggestions from consultants received by mail and telephone.

Information obtained in the survey was organized into readily accessible files for use by interested participants. Materials continued to be accumulated from a number of sources, although most of the work was done during the spring of 1969. Project directors and persons active in research and development responded to requests for pertinent materials relating to their current work. Staff members visited sites of particular interest and attended meetings and conferences. Notes of numerous phone conversations and tape-recorded discussions were transcribed and reviewed. Staff members continued to check current issues of professional journals, magazines, and newsletter-bulletins as well as books and unpublished manuscripts for new sources. Periodically, news releases and notes on controversial issues were published in an effort to evoke reaction and obtain contributions from interested readers.

During summer and fall, the CLUE staff assembled from these published and unpublished sources, five documents containing differing points of view on issues in the use of computers in education. Most of the individual statements within each collection were shortened to sharpen the meaning and some were altered to make them clear when read outside the context of the articles from which they were taken.

Review by Those Whose Material was Paraphrased

Drafts of five statements of points of view were assembled during the summer and mailed to all persons quoted directly and to other interested and knowledgeable specialists in the field. Revisions were made by CLUE staff during the fall and winter based upon comments and criticism received from these participants. Vocal expression of opinion was collected at a symposium of the National Council for Education Technology (United Kingdom) and at small discussion groups assembled at meetings of computer, engineering and educational groups in the United States. A preliminary draft of the entire final report was distributed for review and comment in February, 1970, and the preliminary findings were discussed by critics called by Project CLUE to a special session at the annual meeting of the American Educational Research Association (AERA) in Minneapolis, March 2, 1970.

The next series of revisions and updating of the preliminary draft was made during March and April with additional review at meetings of the Association for Educational Data Systems (AEDS) and the American Federation of Information Processing Societies (AFIPS). The appendices were prepared during the spring and summer and distributed for comment. Several articles summarizing significant findings for publication to wider audiences were completed during the summer. A draft of the final report was presented by the project director to a special conference on Computers in Education sponsored by the International Federation for Information Processing (IFIP) in Amsterdam in August 1970, and the Education Sector of the annual meeting of the Association for Computing Machinery (ACM) in September in New York City. Based on discussion of these meetings and others throughout the fall, the report was revised and extended. Copies of the entire final report will be available through the U. S. Office of Education and the ERIC Clearinghouse on Educational Media and Technology at Stanford University. Some sections will be revised and distributed by The Center for Research on Learning and Teaching at the University of Michigan, for example, the Guide to Information Sources (Appendix A of Volume I).

Coordination With Other Studies

Throughout the project, CLUE staff members coordinated their efforts with those of other projects reviewing the use of computers in education. Material and comment were exchanged with specific projects of similar purpose, among them: a study of the computer in higher education at Rand Corporation, Santa Monica, California, for the Kerr Commission on Higher Education; a survey of computer uses in college teaching with a demonstration of an innovative system at the Sloan School of Management, MIT, Cambridge; program planning by the National Council for Educational Technology, London; and other projects discussed at numerous single conferences and symposia. CLUE staff members helped prepare materials for several conferences and publications, thus contributing to the other projects and at the same time obtaining useful comment from the audiences for use in revision of the document of Project CLUE.

For example, CLUE prepared a package of materials for participants in the National Council of Educational Technology's Seminar on Computers in Education held in Leeds, England, September 8-12, 1969. With revisions, some of these materials were published in the conference procedings. Other significant contributions of Project CLUE to working conferences include: a workshop on contributions of computers to learning and teaching at the Fall Joint Computer Conference in November; a planning session on dissemination of computer-related learning materials for the National Academy of Engineering also in November; a consultation on computer-assisted instruction for Unesco in March of 1970; symposia on planning for secondary and higher education at the OECD Centre for Education Research and Innovation (CERI) the same month; a conference on computers in higher education held by RAND Corporation in October; and a second OECD/CERI planning session on computers in higher education also in October of 1970.

Dissemination and Other Service Activities of Project CLUE

Throughout the project, the staff of Project CLUE pursued activities believed to be useful at the moment to potential users of computers in instruction. Thus useful information was made available previous to and apart from distribution of drafts of the final report.

As noted earlier, the project exchanged materials and ideas with a number of other projects, providing direct assistance to some of them. For example, a set of project abstracts was prepared for the work at RAND Corporation, and a draft of a statement of domain and dimensions of computer use. RAND staff built upon this work and returned their drafts which were of benefit to further writing within Project CLUE.

The files of Project CLUE were open to all who inquired. The files included materials on author languages, student languages, abstracts of projects, selected review papers and technical reports from each project. Other files concerned special areas such as generative technique and dissemination of information. These were reviewed by a number of visitors who came to the Center for various purposes and utilized the CLUE files they found available there, and also by University of Michigan faculty and students. Six of the visitors came particularly for careful search of the literature files and found Project CLUE materials particularly useful.

Successive versions of a Guide to Information Sources were distributed to all persons mentioned in the document; replies received indicated it was helpful to many different kinds of scholars and researchers interested in publications concerning the uses of computers in instruction. Some of the publications annotated in the Guide have been in competition for readers and material, and circulation of the document served to encourage each periodical to emphasize its strengths and maximum contribution to the field rather than compete unknowingly with similar publications without profit to itself or to users of the information services.

Early in the project a quick version of the longer review was produced and distributed through the ERIC Clearinghouse on Educational Media. Project CLUE staff obtained particularly helpful contributions from Robert Morgan at Florida State University and John Feldhusen at Purdue University which were edited and assembled with other materials for distribution by ERIC.

Project CLUE staff also encouraged individuals to participate in meetings such as the Seminar on Computer-Based Learning sponsored by the National Council of Educational Technology. E.N. Adams prepared a paper on languages and systems; Gordon Lyon assembled notes on computer system design; Robert Seidel interpreted some of his work on economics and management. A detailed list of various contributions follows.

Professional Meetings and Associated Project CLUE Papers and Publications

During the study, staff members attended a number of professional meetings to share the study's findings and to receive suggestions and contributions from specialists in diverse fields related to educational technology. Such trips and presentations also further the goal of early dissemination of tentative results and supporting information.

The following list provides a summary of the most significant meetings attended by CLUE staff throughout the project. The date and place of each meeting have been noted, topics of primary concern are indicated, and relevant publications or papers presented at the meetings have been identified.

American Educational Research Association (AERA)

Annual Meeting
Los Angeles, California, February 3-10, 1969

"Instructional Programming Languages: A Five Year Perspective," since published in Educational Technology, Vol. 10, No. 3, March, 1970, pp. 41-43.

Entelek

Midwest Conference on CAI
Chicago, Illinois, February 4, 1969

"Purposes and Plans of Project CLUE" (Handout)

Association for Educational Data Systems (AEDS)

Convention
Portland, Oregon, May 10-13, 1969

American Federation of Information Processing Societies (AFIPS)

Spring Joint Computer Conference (SJCC)
Boston, Massachusetts, May 13-17, 1969

"Computer aids to learning about computing" (Discussion topic)

Association for Computing Machinery (ACM)

Annual Convention
Challenges of Progress in Computing: People, Technology, Purposes
San Francisco, California, August 26-28, 1969

Organized for round table discussions on computer science topics bearing on instructional uses of computing; project CLUE handouts used.

Institute of Electrical and Electronic Engineers (IEEE)

International Symposium on Man-Machine Systems, (ISMMS) St. John's College
Cambridge, England, September 6-11, 1969

"Interactive Programming Languages Adapted for Instructional Use of Computers," with John C. Hesselbart. Proceedings of the First International Symposium on Man-Machine Systems 1969, Cambridge, England, 1970

National Council for Educational Technology (NCET)

Seminar on Computer-Based Learning Systems, Leeds University
London, England, September 8-12, 1969

"Planning and Managing the R&D Programme: A Summary of Discussion," pp. 89-93 in Proceedings of a Seminar on Computer-Based Learning Systems in Education, John Annett and John Duke (Eds.). London: National Council for Educational Technology. 1970, Distributed by Books for Schools, Ltd., through Councils and Education Press, Ltd., 10 Queen Ann Street, London WIM9LD, England. "A Comparison of Languages for Programming Interactive Use of Computers in Instruction." 26-31 in Proceedings.
"Some procedural language elements useful in an instructional environment," with Gordon Lyon, pp. 18-25 in Proceedings.

Institute of Electrical and Electronic Engineers (IEEE)

Systems Science and Cybernetics Group (SS & C)
Annual Conference
Philadelphia, Pennsylvania, October 21-25, 1969

"Analysis of Computer Role in Learning and Scholarly Work" (Discussion topic)

American Federation of Information Processing Societies (AFIP)

Fall Joint Computer Conference (FJCC)
Las Vegas, Nevada, November 18-20, 1969

"Computer Contributions to Learning and Performance: An Outline," Prepared for four concurrent discussions and revised for publication, pp. 6-12 Interface, Vol 4, No. 1, February, 1970

National Academy of Engineering (NAE)

National Academy of Engineering, Instructional Technology Committee
Commission on Education
Newark, New Jersey, November 24, 1969

"Broadening the Base of Users of Effective Computer-Related Learning Materials " (Written recommendation to committee)

American Education Research Association (AERA)

Annual Meeting
Minneapolis, Minnesota, March 2-5, 1970

"Preliminary Draft of Project CLUE Report" (Detailed handout)

Organization for Economic Cooperation and Development (OECD)
Centre for Education Research and Innovation (CERI)

Symposium on Computers in Secondary Schools
Paris, France, March 9-13, 1970

"Implications of on-line systems for an introduction to computer applications and programming," in presented at a Seminar on Computer Sciences in Secondary Education, Centre for Educational Research and Innovation, OECD, Paris.

Unesco

Consultation on CAI in Developing Countries
Paris, France, March 16-18, 1970

"Guidelines for Instructional Use of Computers" (Project CLUE handout; consultation report)

Organization for Economic Cooperation and Development (OECD/PARIS)

Symposium on Computers in Higher Education
Paris, France, March 19-20, 1970

"Requirements for programming languages in computer-based instructional systems," presented at a Seminar on Computers in Higher Education, Centre for Educational Research and Innovation, OECD, Paris 16 (published by OECD, 1971).

City University of New York (CUNY)

Conference on Computers in Education
Princeton, New Jersey, April 17-19, 1970

"Introduction to Instructional Use of Computers: Definition of Concepts and a View of the Future " (Project CLUE handout)

National Education Association (NEA)
Department of Audio Visual Instruction (DAVI)

Annual Conference
Detroit, Michigan, April 28, 1970

"Computers in Education: A View of the Future " (Project CLUE handout)

American Federation of Information Processing Societies (AFIP)

Spring Joint Computer Conference, (SJCC)
Atlantic City, New Jersey, May 5-7, 1970

"Computers in Education: Mechanizing Humans or Humanizing Machines" (panel discussion summary) Published as "Four Viewpoints on Instructional Use of Computers," in IEEE Transactions on Man-Machine Systems, Vol. MMM-11, No. 4, December 1970.

Association for Educational Data Systems (AEDS)

Annual Convention: Education through Technology
Miami, Florida, May 13-15, 1970

National Science Foundation (NSF)

Conference on Computers in the Undergraduate Curricula
University of Iowa, Iowa City, Iowa, June 16-18, 1970

INDICOM

National Conference on Computer Applications to Learning
Waterford Community Schools, Project INDICOM
Bloomfield Hills, Michigan, July 8-10, 1970

"Tentative Findings of Project CLUE in the area of programming languages"
Proceedings in press.

ESC

Engineering Summer Conferences
University of Michigan
Ann Arbor, Michigan, Summer, 1970

"Sample Programs for Instructional Use of Computers" (Demonstration)

Commission on College Physics (CCP)

Conference on Computers in Undergraduate Science Education
Chicago, Illinois, August 17-21, 1970

"Computers in Physics and Mathematics Instruction: Capabilities and Limitations," in Proceedings of a Conference on Computers in Undergraduate Science Education, Commission on College Physics, College Park, Maryland, 1971.

International Federation for Information Processing (IFIP)

World Conference on Computer Education
Amsterdam, Netherlands, August 24-28, 1970

"Instructional use of computers: A critical examination with recommendations for action," with Susan McClintock in World Conference on Computer Education, 1970, R. Scheepmaker and K. Zinn (Eds.), International Federation for Information Processing, Amsterdam, The Netherlands, 1971. "General Report" also reprinted in IAG Journal, Vol. 4, No. 1, 1971.

Institution of Electrical Engineers (IEE)

Conference on Man-Computer Interaction
Teddington, England, September 1, 1970

"Programming Languages and Operating Systems for Specific Instructional Environments," with James W. Conklin, in the Proceedings of the First International Conference on Man-Machine Interaction, Institute of Electrical Engineering, Savoy Place, London, W.C.2, England, 1970.

Association for Computing Machinery (ACM)

Annual Conference, Sector on Computers and Education
New York City, New York, September 2-4, 1970

"A Review of Computer Uses for Instruction: Report on Project CLUE." To be published in the Education Sector of the Proceedings, 1971.

Commission on Higher Education, Carnegie Foundation

Conference on Computers in Higher Education
RAND Corporation
Beverly Hills, California, October 1-3, 1970

"Computer Learning Under Evaluation (Project CLUE) and an Attempt at Hyperspeech." in Computers in Instruction: Their Future for Higher Education, Rand Corporation, 1971.

Organization for Economic Cooperation and Development

Conference on Computers in Higher Education
Center for Educational Research and Evaluation (OECD)
Portland, Oregon, October 26-30, 1970

"Software Problems in Using Computers for Instruction." and other contributions to Conference summary and recommendations, published by OECD, 1971.

Institute of Electrical and Electronic Engineers (IEEE)

1970 Symposium on Man Machine Systems
Winter Park, Florida, November 12-13, 1970

"An Instructional Environment for Interactive Problem Solving Using Computers." (Project CLUE handout)

American Federation of Information Processing Societies (AFIPS)

Fall Joint Computer Conference (FJCC)
Houston, Texas, November 17-19, 1970

"Computers in Higher Education." (Project CLUE handout)

VOLUME II - APPENDIX B

LIST OF PROJECTS CONTACTED

Names and addresses are listed for about 200 projects or offices in universities, schools, government, military, and industry in North America and a few university projects in other countries. All of the organizations were informed about the progress of the study. Most provided information about their activities and CLUE staff worked closely with some of the individuals and organizations listed.

The list is intended to inform the reader about the scope of contacts made during the CLUE study. It may be useful as a mailing list for distribution of material but should not be considered as a list of sources to write for general information. For guidance in an initial search, the reader is directed to Appendix A of Volume I which describes information sources such as reference books, periodical publications, professional organizations and commercial services which meet a variety of needs for information.

The reader interested in instructional uses within a particular subject area should consult the discipline-oriented section of Appendix A in Volume I to determine the professional societies and commissions which were contacted in the course of the study.

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2. Dr. Michael A. Hall, Director BELOIT
Social Sciences Instructional Programming Project
Beloit College
Beloit, Wisconsin 53511

3. Mr. Melvin Ferentz, Director BROOKLYN
CAI Research Center
Brooklyn College
Brooklyn, New York 11210 (212) 780-5271

4. Dr. M. E. Maron, Deputy Director CALIFORNIA/BERKELEY
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5. Mr. Robert M. Gordon, Director CALIFORNIA/IRVINE/CF
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6. Dr. William T. Blessum, Director CALIFORNIA/IRVINE/MED
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11. Dr. Robert S. Tannenbaum — COLUMBIA/CAI
Coordinator of Computer Assisted Instruction
Research and Demonstration Center for
Education of Handicapped Children
Teachers College
Columbia University
525 West 120th Street
New York, New York 10027

12. Dr. Benjamin Rosner, University Dean — CUNY
City University of New York, CUNY
535 East Eightieth Street
New York, New York 10021

13. Dr. Thomas E. Kurtz, Director — DARTMOUTH/CC
Kiewit Computation Center
Dartmouth College
Hanover, New Hampshire 03755

14. Dr. Edmund D. Meyers, Jr., Director — DARTMOUTH/IMPRESS
Project IMPRESS
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15. Dr. John Schurdak, Director FAIRFIELD
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16. Dr. Duncan Hansen, Director FSU/CAI
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17. Dr. Guenter Schwarz, Director FSU/CRICISAM
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18. Dr. Lawrence M. Stolurow, Director HARVARD/CAI
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19. Dr. David V. Tiedeman, Director (on leave 70-71) HARVARD/ISVD
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20. Dr. Anthony G. Oettinger HARVARD/CAIR
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66.	Mr. Robert E. Hoye, Director Instructional Media Laboratory University of Wisconsin--Milwaukee Milwaukee, Wisconsin 53201	WISCONSIN/IML
67.	Dr. Philip Lambert, Director Instructional Research Laboratory 308 Education Building University of Wisconsin Madison, Wisconsin 53706 (608) 262-3888	WINCONSIN/IRL
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3. Dr. Eric D. McWilliams — CORNELL/FLARCO
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17.	Mr. James H. Wiggins Sterling Institute Suite 3750 Prudential Tower Boston, Massachusetts 02199	STERLING
18.	Mr. Robert E. Gustavson, Treasurer Synergistics, Inc. Ten Tech Circle East Natick, Massachusetts 01760	SYNERGISTICS
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VOLUME II - APPENDIX C

ACTION PROGRAMS FOR PROFESSIONAL SOCIETIES AND OTHER GROUPS

Discussions of the contribution of professional societies and other gruops to effective development of computer uses were frequent during Project CLUE deliberations. Excerpts from those discussions have been brought together in this appendix for the information of interested persons. Section 4 of Appendix A of Volume I provides a sampling of present activities and programs within professional societies and related gruops.

The ideas and tentative proposals put forth should be further developed by a panel, working group or special project for which the role of the professional society, commission or library is a major concern.

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    b. Bulletin on computer uses in education
    c. Bibliographies and surveys
    d. Current awareness service
    e. Arrangements for one-to-one exchange of materials and personnel
    f. Assistance on planning professional visits

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1. Possible Action Programs

a. Journal Publication and Review of Computer-based Learning Materials

Publication and review of computer-based learning materials in journals serves many useful purposes. By bringing professional credit to the author, the publication encourages him to give time to the writing and maintaining of institutional programs. By publishing only refereed reports of materials available an important check on quality and relevance is introduced. Finally, reviews by qualified persons offer potential users reliable information on which to base selection of materials.

Computer-based learning materials need to be reviewed just as textbooks do. However, many journal editors may require encouragement to solicit such material and advice on how it may be most usefully reviewed.

It has been difficult to find reviewers who are skilled in three areas: the discipline of study, teaching in that subject area, and instructional technology. Each journal, of course, will emphasize the main interest of its readers. A discipline-oriented journal is likely to stress the subject matter while technical comment on instructional procedures appears in educational technology or psychology journals. Still, the reviewer must have some familiarity with all three fields.

To be most constructive, reviewers should consider computer-based materials as experimental or exploratory. Thus the procedure of evaluation may be criticized and the results may be right or wrong, but the materials themselves are neither good nor bad because of these research considerations. Some common problems observed in reports on available materials are premature evaluation, preoccupation with test data, lack of imagination in the evaluation design and a compulsion to label results as either a dramatic success or a dismal failure.

Matters to which reviewers might pay particular attention are: 1) the extent to which the computer contributes to the effectiveness of the learning materials; 2) the rationale for the instructional strategy used, and 3) the translatability of the exercise to other computer systems. Sample guidelines which elaborate on these and other points should be prepared.

Some journals have recognized the need to disseminate information about computer-based learning materials, even to provide a library of programs in computer-readable form, e.g., the American Journal of Physics. Its policy grew out of a 1965 conference sponsored by the Commission on College Physics.

Besides its usual requirements for publication, the Journal lists three criteria for acceptance of computer programs: a) the exercise must have been tested on a significant number of students; b) the program must be useful at other computer installations; c) the author must allow unlimited reproduction of detailed information, including machine listing of the program, so the Journal can avoid copyright problems.

The Journal publishes an extended abstract of the program. Six items are included on single lines immediately above the abstract text to give the basic information at a glance: subject area, level of student, time spent by student (thinking and typing as well as computing time), programming skill of student, programming language, and hardware requirement. The 400-word abstract discusses the physics of the problem, the respective activities of the student and the computer, and the teaching effectiveness of the problem in an actual trial.

At the same time that the contributor submits his abstract, he also sends the Journal on good, white stock two clean copies of: a) a listing of the program in the language indicated in the abstract; b) a typical student's interaction with the program; c) logical flow diagrams if available; and d) any literature given to the student in connection with the exercise.

all materials submitted are forwarded to a referee who reviews the contribution. If it is accepted for publication, the detailed description of the program is sent to the Commission on College Physics where it is photographically reduced, if necessary, to simplify the duplication and distribution problem. Distribution of punched cards or tapes of programs by the author is encouraged but beyond editorial control. Nevertheless, the Commission counts on contributors to make reasonable efforts to cooperate with a colleague's request.

b. Libraries of Computer-based Materials

Regional or national libraries of computer programs and related documents provide a promising way in which to assist prospective users of computer-based materials in locating, reviewing and selecting those which might be useful for their needs.

Such a library should not attempt to cover computer-based learning materials for more than one discipline or profession (such as chemistry or architecture) although a wider grouping (such as the humanities) might be an appropriate beginning in areas of few applications. Some have also suggested that the geographical region served by each library should also be restricted to encourage site visits which facilitate collection, confirmation and distribution of effective and relevant materials.

Organizations in several subject areas are already experimenting with such services. EDUCOM's Education Information Network (EIN) illustrates a general type of interinstitutional activity. EIN has assembled a directory of programs operating on university computing systems in a wide region. The important contribution of EIN was to be the facilitation of access by arranging computer access and convenient billing. However, EIN has not given particular attention to the problems of fitting instructional packages prepared for one environment to another one. Such a service would require staff prepared to assist in documentation and maintenance of programs.

Another kind of service is provided by libraries and distribution systems set up by various regional computing services: Triangle Universities Computation Center in North Carolina and Cooperative Venture in College Curriculum Development at the Illinois Institute of Technology for the Chicago area are notable for their size and history of service. Many others (about fifteen are supported by the National Science Foundation) have begun program libraries. In fact, the success of such network operations presumes the existence of libraries rich in programs relevant to the current needs of users.

Yet a third kind of interinstitutional service is that exemplified by the program file being assembled by staff at the Northwest Regional Educational Laboratory. As part of Project REACT the staff is soliciting material from as many sources as possible, reviewing and preparing abstracts to describe the the essential features of the materials and how to obtain them. The abstracts are included in a reference catalog which is updated every few months and available on request. The catalog is arranged by clusters of subjects or curriculum areas, and includes materials which focus on student-written programs as well as those which use "canned" programs as an instructional device.

c. Conferences Involving Vendors, Publishers, Authors, Users and Sponsors

If computer-based learning exercises are to be widely used, improved methods of documentation and dissemination are necessary to translate programs from one system and educational institution to another. One step toward better distribution of materials may be conferences of equipment manufacturers, authors, publishers, and the administrators and users of computer-based educational systems.

The basis for discussion at such a conference should be background papers prepared in advance to propose standard practices for documentation of learning exercises and outlining ways in which to encourage making materials prepared for one system usable on others. The papers might be prepared by selected experts in the field and reviewed by a sample of vendors, publishers and users before the conference.

Participants in the conference should include representatives of the publishers and equipment manufacturers such as IBM, RCA, Philco-Ford, Westinghouse, Univac, Honeywell, Computer Curriculum Corporation, Random House, Harcourt Brace and Javanovitch, McGraw-Hill, and Science Research Associates, probably inviting no more than ten to participate in active discussion. To facilitate this discussion the number of administrators and users of computer-based educational systems might also be limited to about ten selected for their interest in promoting transferability of materials. They should represent different student levels and topical areas of education. Other persons could attend as observers.

The conference would encourage users to state their needs clearly, publishers to state the requirements of production and distribution, and vendors to specify the economic and technical restraints on further system development. As a result, new channels for continuing interaction among organizations and among individuals would be established.

These benefits could be shared through an action-oriented report which should include a careful assessment of current needs and recommendations for further steps to develop standards, organize centralized files of information and programs, and encourage publication and review of computer-based learning materials.

2. The Role of Sponsoring Agencies

Potential sponsors of computer-related activities should support conference and review activity as well as individual projects. Instructional use of computers is reaching a stage where it may be as important, or more so, to promote the exchange of information about specific materials and operations than to invest in independent development projects. This should in no way conflict with the essential support for continuing research activity.

Agencies might take a more active role in discouraging independent work which is likely to duplicate work already in progress or completed. In part though the conference activity proposed in the previous section, in part through some kind of clearinghouse to be established, it should be possible to be appropriately selective in funding of new projects. Some agencies already identify project proposals which are independently conceived and would be executed at the expense of coordinated work; some of the clues are: failure to reference the work of a similar nature by others; failure to plan for the effective dissemination of findings from a developmental or exploratory project; failure to provide for the exchange of on-going work throughout the project.

In light of the advice to support conference activity and discourage independent and duplicating efforts, sponsoring agencies should not overlook possibilities for exploiting commercial interests and profit-making investments in computer use in education. A number of the demonstrations by research and development centers in the universities can now be as effectively accomplished by operational projects within the private sector. Some kinds of hardware development, most of the software development, much of the publications activity, and other service functions can be handled well by the profit initiative. University and school groups and non-profit research centers continue to open new ground, explore far-reaching implications of computer techniques, pursue research and evaluative studies, and otherwise help to move the field ahead. However, it should not be necessary to subsidize the routine publication of computer-based learning materials, the establishment of libraries of materials, etc., except at some minimal level to convince the private sector that the service is viable and profits are possible. Of course, it is essential to support the continuing review activities of professional people in the field. This leads to the last point, and one particular to government agencies.

A blue ribbon panel on computer uses in education should be established. One or more professional societies might be involved; more likely it would be associated with the National Institute of Education or National Academy of Sciences. The function of one or more such panels would be to keep a watchful eye on the development of the field, the role of commercial interests, the extent to which institutional needs are being met, the distribution of research and development monies from federal and foundation sources, etc. Representation on such a panel should include the university R&D centers, university and college administrations, administrators in the public and non-public pre-college schools and individuals from non-profit and profit-making organizations likely to make a personal contribution to deliberations of the panel.

In each of the above considerations the sponsoring agency should recognize distinctions among different kinds of effort regarding computer use in education. Different sets of labels have been used; the important point is not to confuse activity intended to develop new knowledge with that intended to bring services into the schools and colleges. More specifically, basic research activity should not be slighted at a time when emphasis is being placed on increasing operations. Furthermore, the developmental and evaluative studies should not be expected to handle large numbers of students. Finally, the operational activities should be shifted to permanent sources of funding to provide continuity.

3. Participation in International Activities

Nearly every project newly engaged in research and development in the area of computers in the instructional process begins with a review of what has been done and what else is in progress. Significant developments in a dozen countries require attention. Maintenance of a current and comprehensive library of international scope is far beyond the resources of individual projects for collection, translation, abstracting and interpretation.

Functions of effective information exchange should be assumed by international organizations such as OECD, UNESCO and perhaps IFIP. Only these kinds of organizations can assemble the necessary talent for selection and interpretation of the valuable work. Increasing numbers of technical reports, theoretical papers, research notes and opinion statements are being placed in limited circulation each month.

Some information functions crossing national boundaries shall be handled well by publishers of international stature but they should be provided sound direction by some group of professionals; eventually most information exchange functions can be placed on a paying basis, but initially some subsidy is necessary. Individual governments and international sources of funds should support fellowships, interpretive summaries and documentation. Individual projects will pay for exchange of documentation and personnel of particular advantage to them. Most of the publications activity can be supported by subscriptions through commercial publishers.

Along with exchange of documents, one should plan for exchange of information about projects and persons interested in one-to-one interchange. Such information files can also be arranged to advise projects and individuals about opportunities for participation in a research program at another site, or professional visits when on a trip or in attendance at a conference.

The general recommendations of recent meetings organized by OECD (March) and IFIP (August) include suggestions for an annual conference, working groups and personnel exchange through fellowship programs. Mechanisms for information exchange are suggested here under six headings, each with brief indication of the options and opportunities available for initiation of the service. Elaboration of these options and action recommendations should be a first order of business for the next meeting of an international planning group assembled to organize mutually beneficial activities regarding instructional use of computers; the U.S. Government and individual projects should give full cooperation.

a. Library of research documents, project descriptions, instructional material descriptions, etc., all available in French and English at least.

   Two options are to begin with:

   1. Education Resource and Information Center (ERIC) in the U.S., especially the Clearinghouse on Educational Media at Stanford University, collaborating with a similar European center providing translation.
   2. Files at OECD's CERI or IFIP's IAG, or any project which has a sizeable library of international literature and facilities for translation.

b. Bulletin on computer uses in education, published on a regular schedule and distributed widely.

   Four ways to get started:

   1. Newsletter of the ERIC Clearinghouse on Educational Media (USA).
   2. Instructional uses section added to Computer Education (UK).
   3. Bulletin of the ACM Special Interest Group on Computer Uses in Education (USA).
   4. A new bulletin or "letter journal" to be established by OECD-CERI, IFIP or a similar organization, probably in cooperation with an international publisher.

c. Current and interpretive bibliographies and surveys, at times highly selective, distributed with a periodical or on request.

   The authors might be:

   1. Library and bulletin staff implied by Recommendations 1 and 2
   2. Experts commissioned by the institution or agency sponsoring the library and/or bulletin.
   3. Contributors to an annual conference selected on the merit of their presentations.

d. Current awareness service, distributing selectively to projects and individuals according to interest profiles provided by them as users of the service.

Three factors will affect the success:

1. Preparation and effective use of an expandable set of descriptors.

2. Prompt and reliable classification of documents.

3. Reliable data on use and satisfaction with which to assess the improvement of the system.

e. Other arrangements for exchange of documents and materials (and perhaps personnel) directly between two projects or individuals.

A central organization can facilitate interchange by providing:

1. Directory of projects and individuals giving interest profiles and mailing addresses.

2. Assistance in making arrangements for personal visits and for exchange of personnel.

3. Encouragement for government-sponsored fellowships designed to bring in scholars from other countries.

f. Assistance on planning professional visits during trips, especially in association with meetings.

1. Whatever information service may be established (library or bulletin or whatever) could also maintain a list of places to visit and information about suitable times, duration and person to contact.

2. A special announcement of places to visit nearby a Conference site could be worked out with affected project directors who are willing to take a small group of visitors before or after the Conference.

3. The breadth of experience available through Conference site visits is broadened if Conference locations rotate among interested countries; bringing in a Conference also encourages new activities at each nearby host site.

VOLUME II - APPENDIX D

PROJECT NOTES ON COMPUTER SYSTEMS DESIGN FOR INSTRUCTIONAL USES

Many working papers on computer languages and systems were prepared during the project, most of them for presentation and discussion at conferences and symposia. Those believed to have some interest for specialist readers are described in this appendix by a summary or detailed table of contents. When the source of the full copy indicated by the reference is not convenient, address inquiries to the director of Project CLUE.

This appendix is included for the convenience of readers interested in technical aspects which received attention during the project. It should not be used as a tutorial on computer science considerations, or a complete study of computer science contributions.

CONTENTS

1. Technical Considerations in the Design of a CAI Computer System — E. N. Adams — 3

2. Some Procedural Language Elements Useful in an Instructional Environment — Gordon Lyon and Karl L. Zinn — 5

3. A Man-Machine Perspective on Instructional Use of Computers — Karl L. Zinn — 7

4. Implications of On-line Systems for an Introduction to Computer Applications and Programming — Karl L. Zinn — 16

5. Programming Languages and Operating Systems for Specific Instructional Environments — Karl L. Zinn, James W. Conklin — 19

6. Requirements for Programming Languages in Computer-Based Instructional Systems. — Karl L. Zinn — 22

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Technical Considerations in the Design of a CAI Computer System
E.N. Adams
Prepared for NCET Seminar on Computers in Education, Leeds, England,
September 8-12, and for Project CLUE

ABSTRACT

An enumeration of technical considerations that govern the design and specification of a CAI system. The discussion is in three parts: first, constraints that are external to the educational applications, second, psychological and pedagogical desiderata, and, third, some of the major features of education systems at the program level.

CONTENTS

- GENERAL INTRODUCTION: CONSTRAINTS
  - Trends in equipment
    - Terminals
      - data rates
      - remoting
      - special fonts
      - hard copy
    - CPU/OS Environment
      - operating system
    - subsystem
      - programs
      - courses
- INSTRUCTIONAL CONSIDERATIONS
  - Learning tasks
    - content
    - mediation (communication medium)
    - control aspects
      - scoring
      - valuation

PROGRAM FEATURES

- Author languages
  - functional capabilities
- Program preparation
  - content independent of code
  - control localized and free of content
  - answer processing separate from scoring
  - control separate from learning tasks programs
  - differentiation of roles
- Operational aides for
  - proctors
  - operators
  - supervising teachers
  - students

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Some Procedural Language Elements Useful in an Instructional Environment

Gordon Lyon and Karl L. Zinn

INTRODUCTION

The instructional environment demands of a programming language features not easily satisfied by any one implementation. Some users will program instructional modules central to the system; these require efficient and probably reentrant machine code. On the other hand a student may be asked to modify a program or write a new one himself as part of an interaction; in this case an interpreter probably serves better than a compiler. Furthermore, the executive system may itself hinder or preclude desirable elements, such as general classes of files. Such a variety of requirements forces a general discussion into a framework of general features for a hypothetical programming language, comparing existing languages against the paradigm.

Of six languages considered in this paper, some are compiler-implemented, a few are specifically interactive and well-suited for student use, three are powerful enough for systems-modules, one is an extention of a common scientific language (Fortran IV), and one is the latest (probably last) 'superlanguage' (PL/I).

CONTENTS

INTRODUCTION
  - Caveat
  - Problem-Oriented Languages
  - Instructional Demands on a Language
  - Procedural Elements

PROCEDURAL LANGUAGE ELEMENTS IN AN INSTRUCTION ENVIRONMENT
  - The Basic Choice
  - Empahsis of the Discussion
  - Names, Data Representations, Variables and Storage Acquisition
  - Files and Input/Output

Statements and Modules
  Procedures
  Tasks, Parallelisms
Interrupts
Other Points
Summary
THE LANGUAGES (PL/I, APL, CATO, BASIC, PIL, STRGCOMP)

APPENDIX A: Some Requirements in Instructional Languages
APPENDIX B: Elements from a Hypothetical Instructional Language
APPENDIX C: An Example of the Use of Macros
REFERENCES

Published in Proceedings of a Seminar on Computer-Based Learning Systems in Education, John Annett and John Duke (Eds.). London: National Council for Educational Technology, 1970. Distributed by Books for Schools, Ltd., through Councils and Education Press, Ltd., 10 Queen Anne Street, London WIM 9LD, England.

A Man-Machine Perspective on Instructional Use of Computers
Karl L. Zinn

EXCERPTS

Four articles have been brought together for this Transactions in an attempt to interest members of the Man-Machine Systems Group and other readers in making some contribution to the effective use of computers in the instructional process. From a number of possibilities I selected four which together suggest the variety and the depth of man-machine system contributions to computer uses in education. It is clear to me that engineers should be interested in the problems of educational economics, effectiveness and relevance; perhaps these four reports will succeed in demonstrating that they could make a useful contribution to computer-related instructional systems and learning environments.

I have not tried to be complete in the representation of applications of computers and systems analysis to learning and instruction. Another perspective on computer contributions to learning and performance is provided by the notes of a session on "Computers in Education: Mechanizing Humans or Humanizing Machines" printed in the February and June issues of Interface, the Bulletin of the ACM Special Interest Group on Computer Uses in Education.

Ten years ago the initial projects on computer-based instruction depended upon creative effort of computer scientists, engineers, psychologists and humanists; many of the early developments were suggestive of significant computer contributions to the educational process. The most interesting learning exercises appeared to result from insight into the processes of learning and problem solving combined with understanding of the possibilities and limitations of automated information processing. Critics of computer-assisted instruction today point out that the actual benefits have fallen far short of what potential users were led to expect.

During the middle of the last decade the most visible research and development programs were directed by educational technologists, most of whom were not also expert in computer technology and information systems. Even when the educational research and materials development were of good quality, the computer was not well used, and computer-assisted instruction (CAI) acquired the reputation of an unimaginative, costly, page-turning teaching machine. I have tried to assemble a sampling of project reports which are suggestive of the contributions to be made by the insightful engineer and teacher to research and development of instructional use of computers.

Problems with CAI in the First Decade

The dificulties encountered by educational technologists using computers in the last decade can be characterized by a brief analysis of the present status of programming techniques for specifying instructional strategy. The intriguing idea that the programming of an automated instructional procedure could be immediately accessible to a classroom teacher or textbook author without training in computer use led to the preparation of numerous "author languages" which were to bring computer tutoring aids into every classroom. However the simple languages only encouraged trivial uses, and the programming for any instructional strategy other than the uninteresting one the language designer had in mind was found to be extremely tedious.

Many of the potential authors of computer-based courses felt that the machine should be able to recognize all meaningful entries by the student users no matter how various and peculiar they might be; some authors attempted detailed descriptions of endless possibilities of input, but their resolve did not survive more than a few short units of instruction. The processing of student input by word and character searches specified in detail for each anticipated answer will not provide the reliable discrimination necessary for program control of the dialogue between student and machine. Special character editing procedures, phonetic encoding of an input string, comparisons by character counts, allowances for character transpostions, numerical approximations and other extensions and additions to the instructional programming languages have not eliminated the difficulties.

The computer has been singled out among education media for its infinite capability to branch depending on the response and individual characteristics of each student. However, selection among a few alternative frames of information and questions prepared in detail in advance does not have sufficient adaptability or economy to justify the computer role in control of audio-visual media and stimulus sequences, except perhaps in situations where students with high need will not otherwise receive attention, those culturally distant from their teachers, and special education students in systems where individual attention is not provided.

Language designers responded to the expressed need for facilities to better individualize CAI by adding to existing languages statements which access and manipulate additional data such as error rate, response latency, previous performance and attitude measures, but most of the effort was misplaced and the situation is not much improved for operational instruction aids in the schools. The task of the author planning substantial curriculum development still is unreasonable within the constraints of the instruction models implicit in CAI languages.

A few of the projects based more in computer science rather than in educational psychology indicate the prospects for new techniques of programming procedures and describing data bases of curricula which are more powerful in the sense of accomplishing more student hours of effective instruction for the same author investment.

Research which is rather elaborate and usually quite costly is in progress for which the general goal may be characterized as "humanizing the machine" by making the conversation the learner has with the computer program more like one he might have with a human tutor. Initial results of these experiments are encouraging but not adequate to consider having practical operations in the schools within the next ten or twenty years. Linguistic processing of unconstrained English is costly and produces only approximate results.

Adding Knowledge to the Automated Tutor

The papers in this collection include two viewpoints on the preparation and use of a structured data base with generalized procedures for generation of instruction and testing material or for responding to learner-formulated questions. Generative procedures have attracted the attention of educational technologists because of the fresh promise of automatic construction of instructional programs tuned to the current needs of each individual learner. Generation is easy and encouraging for highly-structured subject matter, but the dynamic adjustments or "tuning" require comprehensive and inter-dependent information structures, and some insight about human learning and cognition, at least as observed within the particular area and topics of instruction.

The papers of Wexler and Carbonell present in some detail two approaches to putting some "knowledge" and "intelligence" into an automated tutor, and yet leaving important options about use of the information processing resources in the hands of the student. Carbonell includes his interpretation of other work in the field, and the general contribution of artificial intelligence research to computer assistance for instruction.

Both authors have recently completed substantial dissertations and the reports included here speak for themselves. Neither of the two claim to have a tool near ready to put into operation in the schools. Both are information scientists who are as interested in artificial intelligence and related research topics as in educational technique and practice. However, Carbonell points out that he uses human tutoring practice as a guide more than a goal, and at times he has been willing to yield the generality desired by artificial intelligence researchers for the practicality of student-machine communication. I believe that the major obstructions to transition from research to application in some way relate to attempts to make the computer respond as a human would to whatever a learner may wish to say.

Perhaps an adjustment of goals for information-file-oriented and generative efforts and a reapplication of techniques will sooner achieve some impressive and potentially economic benefits for learning. I would like to see greater attention given to effective interaction between man and machine during the learning process: What should be done by each person involved, and what should be done by the machine? I visualize a dynamic information system which serves as an interface for a scholar and learner; could they share a computer-based, primary-source "textbook" which is being updated continually by the scholar and annotated occasionally by each student who uses it?

Serious students and conscientious university professors sometimes work together in an effective way when a book is being prepared; this opportunity could be extended to any student and instructor willing to invest some minimal effort to use an innovative system. The institution of the college lecture has been described as "the least efficient means for getting partial information from the notes of the professor to the notes of the student - without its passing through the heads of either." The new style for educational institutions and student-professor relations suggests that a common working environment including the notes of the professor in addition to various primary sources of information would be quite welcome.

In a similar way an automated information system could help a learner and teacher share a common working environment for hypothesis testing, sometimes artificial as in computer simulation of physical and social processes (e.g., a model of evolution), and sometimes real in the sense of actual data from experiments (e.g., election returns or radiation measures).

Automating Tools for the Human Learner

Some have suggested that the best way to improve the contribution of computers to instruction and learning is to increase the accessibility of information processing tools for learners and other users. A large number of projects, most of them not considered to be CAI, have shown viable alternatives to strictly specified instructional strategies for computer use in the schools today. I have included in this issue reports on two related projects which together point out one of the major pedagogical problems faced by those introducing information processing tools for student use: monitoring student use of the tools and determining when it is important to intervene to guide their use for more effective learning and later performance.

Feurzeig and others report on an effort to prepare a generalized technique for processing a student's programs and monitoring his progress toward solution of a problem set for him. At this stage of development the lesson designer is required to provide considerable detail about each individual problem. More generality can be achieved but at the expense of automated guidance in problem solution. In any case, the designer of a learning exercise using this approach tries to exploit current system capabilities for convenient use by students and teachers without extensive training in computer programming.

Rosenberg and others report development of a system with a particular task orientation. The aids to model construction provided by systems such as Rosenberg's ENPORT may facilitate learning for students of any age. Presumably the notation, data structures and communication devices are selected to serve well the particular subject matter and age level. A language (or subsystem) such as ENPORT and its associated material should be responsive to learner initiative and encourage exploration of procedures.

Simulation, gaming, information organization and retrieval and other tools facilitate the establishment of environments for student "discovery" of concepts and procedures and should foster a general strategy of intellectual inquiry. To begin with very simple models and then increase learner-designer initiative may be an important factor in the success for this mode of computer use.

Roles for Man and Machine

At an education session of the 1970 Spring Joint Computer Conference, Thompson spoke with some enthusiasm for promoting inquiry and student discovery in the instructional use of computers. He pointed out that in tutorial CAI most of the preparation time is invested in guessing what errors the students are likely to make and preparing diagnostic materials. Thereby, materials which take over two thirds of the author's time to prepare may be seen by less than one third of the learners, and then only after they have been led to making errors.

On the other hand, when using the computer for the facilitation of discovery, full attention is given to the positive development of course material. The conceptual systems that are characteristic of discovery aids can be prepared in a rich and enticing form that facilitates the learning experience of the student and reinforces that experience by providing a multitude of pathways for self-guided exploration and discovery.

The generative systems of Carbonell and Wexler, especially when used in a question-answering mode and with an expansive and organized information base, provide one step around the problems faced by tutorial CAI today. Given two and three-dimensional representations of the internal structures arranged for direct viewing by learners, and assuming increased sophistication of young people regarding computers and information systems, I predict an important stage of exploration and application of man-machine interaction in education. The model-building and program-checking systems of Rosenberg and Feurzeig, especially when the learner is well informed about the tools given him for use with few constraints, provide another and perhaps more immediate step toward effective computer use in the schools.

In all, my disappointment with instructional use of computers to date appears to be attributable to a failure of most developers of CAI systems and learning materials to assign to the machine those things it does best for each human learner at each moment, and reserve for the human the things he does better for himself.

Full copy of this editorial and four papers were published in:
IEEE Tansactions on Man-Machine Systems December 1970.

Implications of on-line systems for an introduction to computer applications and programming

Karl L. Zinn

Notes assembled for a seminar on computer sciences in secondary education,
Center for Educational Research and Innovation, OECD
Paris, March 9-14, 1970

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SAMPLE PROGRAM EXCERPTS

OUTLINE OF CONSIDERATIONS FOR INNOVATIVE DEVELOPMENTS

I. General considerations:

A. Flexibility, e.g., language implementation within a general-purpose system, will enable a systems group to explore new ideas and encorporate those which show promise in preliminary use.

B. Language designers should recognize different uses have different needs. Is the user learning to program, computing a statistic, processing text, running a simulation, building a model,...?

C. In an operational setting, a subsystem, language subset or applications package may be tuned to the needs of specific users; student, instructor, and lesson designer each require a different kind of support from the system and a different style of training.

II. Interactive mode considerations, especially for the infrequent user:

A. An immediate and responsive reply from the system will encourage efficient and effective use.

B. Rules and conventions should be easy to learn and later recall when working at the rapid pace of conversational interaction.

C. A comfortable dialogue is possible in which the computer processor neither dominates nor leaves the user "in the dark." The system should be engineered so that the user can do for himself things he does better than the machine, and the machine serves the user in its area of strength.

D. Flexibility during a working session will encourage a user to test out an idea, compare different versions of a subroutine, save procedures for future use, and select the most economical as well as the most convenient of alternates.

III. Categories of specific needs:

A. Input and output: devices; data rates; and formats.

B. Files: temporary and permanent; common and private; sequential and indexed; cost and accessibility; editing; and searching.

C. Storage allocation: static and dynamic; arrays and lists.

D. Names: mnemonics; equivalences and abbreviations; implied conventions and implicit variable types; and name-table sizes.

E. Data representations: arithmetic, logical, string, pointer, and procedure.

F. Definition and use of special routines or extensions: single- or multiple-line definitions; parameters; macro or subroutine; linkage to other processors; subroutine call or operator or new statement type.

G. Interrupts: automatic and controlled; protection from unknown language features; elapsed time or other set condition.

H. Access and control; direct and indirect statements; self-modification of program statements; execution of any string as a program statement; examination of present state or history of execution; step control and tracing of execution.

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Paris-XVIe, France

Programming Languages and Operating Systems for Specific Instructional Environments

Karl L. Zinn, James W. Conklin

SUMMARY

Desirable characteristics of environments for self-instruction and student research are listed with particular attention to the potential contributions of computers and procedure writing to each discipline. Experience with computer use by teachers and students in various academic areas at the University of Michigan is described briefly to exemplify the general specifications. A set of features is proposed for a programming language and operating system from which can readily be derived a convenient programming facility adapted to each discipline and problem. Practical use within a pedagogical context to promote learning and scholarly work by students is a primary consideration throughout.

Desirable features of interactive problem solving environments.

Part of the success of interactive programming languages such as JOSS and BASIC can be explained by the ease with which these languages are learned and initially used. Much of the advantage could be achieved with a similar convenience available readily through a batch-oriented system of suitable response time for the learning and practice task involved.

The essential contribution of the interactive mode of work must involve responsiveness of the system: relevant reaction to the efforts of the user; and provisions for encouraging effective response of the user to the system effort. Responsiveness of a processor during preparation and execution of a program is a key for the casual and infrequent user to unlock the special benefits of procedure writing and testing of algorithms. For example, the occasional user is well advised to try an idea (an expression, an untested subprocedure, or a new output format), even though only partly formulated, and let the computer show him how much can be processed and what the results might be. Furthermore the processor can "guess" at what the user intended, begin executing the instructions, and accept an interruption and clarification as soon as the user recognizes that the procedure should be changed.

On-line conversational use of computers is almost certain to be more costly than less gleamorous means of access to information processing aids, but the cost is justified if the infrequent computer user is able to carry on an effective dialogue with the system. His attrtude toward computers and their uses in his discipline may at times be as important as his particular accomplishments with the specific content skills to be learned.

Adding limited computational capability to an existing coursewriting language cannot be as helpful as adding whatever "course writing" aids may be necessary for effective computer use to an existing computational language. A broad procedural base promotes the information processing capabilities of the computer (rather than the coursewriter designer's conception of what an automated tutorial ought to be), the relevance of the computer to the discipline, and the student access to the program underlying the learning exercise.

In most instructional situations the teacher or the lesson designer would like facility for opening and closing access to various levels of use, and perhaps to specific features at each level. For example, the student learning from a computer-based game or situation can become the "instructor" when setting up a new exercise for another student. The author can become a researcher exploring models on which his learning games are based. Even the applications programmer can become a "systems" programmer, if he can move from the level of programming in a given language to the design of new language features.

The system designer (or an experienced programmer) can, on the basis of discussion with a subject expert, add to the language those statement types which service the particular needs of the problem. The subject expert should find this second-level notation convenient for building models and for embedding them in a suitable learning situation. The student user of this system works at a third level, interacting with the model at first only through the abstract simulation as a management game to be played. If the lesson designer provides the student with a means to "unlock" the features of the processor by which the model may be manipulated in simple ways, the student may explore its parameters and perhaps arithmetic expressions and logical conditions. The student then is permitted to move down to the second level, to design entire models or simulated situations. Whenever the task-oriented features of the language are not adequate to the model building and testing, the experienced programmer is again called in to extend these capabilities to meet the needs of the discipline-oriented users.

This conception can be represented in part by an arrangement of successive shells with permeable boundaries. The system configuration lies at the center of the sphere, and the system programmers build up a shell around it to make useful functional capabilities accessible to applications programmers. They in turn produce the routines and packaged procedures which provide convenience and power for the discipline-oriented user, who may then adapt these task-oriented procedures for convenient use by students in suitable pedagogical content. The outer three or four levels are the ones of primary concern in this paper: instructional use; discipline-related packages and applications programming; and modification of the processor and system features.

Because of the variety of instructional strategies, intended learning outcomes and writing habits, it is not feasible to include all the desired aspects of this multi-level situation in a single language. More appropriately one works within a system which provides the necessary building blocks and the means for linking them together into individualized versions of a processor or package of processors.

Full copy published in: Proceedings of the First International Conference on Man-Machine Interaction, Institute of Electrical Engineers, Teddington, England, September 2-4, 1970.

Requirements for Programming Languages in Computer-Based Instructional Systems

Karl L. Zinn

Prepared for a meeting on computers in higher education,
Center for Research and Instructional Innovation, OECD
Paris, March 19-21, 1970

CONTENTS

INTRODUCTION

- Purposes
- Audience
- Sources of other interpretation and opinion

KINDS OF INSTRUCTIONAL PROGRAMMING

- Organizing the content and preparing the procedures
- Description of successive frames or items
- Provision for conversation within a limited context
- Description of a standard procedure by which material is presented
- Specification of an environment for programming and problem solving
- Relative use of the four kinds of programming

RECOMMENDATIONS

- Maintain flexibility
- Adapt to specific uses and users
- Exploit interactive mode of computer use
- Relate language maintenance and system operation to project goals

STATEMENTS OF POSITION OR POINT OF VIEW

- Contents of this section in detail
- Assessment of a language and system
- General implications of a language for strategy of instruction
- General consideration of universality
- System limitations on language
- Design considerations
- Interactive mode contributions to learner and author

REFERENCES WITH ANNOTATIONS

GLOSSARY FOR COMPUTER USES IN EDUCATION

REFERENCES WITH ANNOTATIONS

Adams, E.N., "Reflections on the Design of a CAI Operating System," AFIPS Conference Proceedings, Vol. 30, 1967 Spring Joint Computer Conference, Thompson Books, Washington, D.C., (SJCC), pp. 419-24.

The problems which Adams had to work around in the IBM 7010 experimental Coursewriter are typical for CAI systems which used available equipment. Many technical problems may be solved for instructional users by following developments in general-purpose systems.

The core partitioning and disk-fetch problems discussed are alleviated in a virtual-address environment. Use of drum and relocation hardware are more suitable than the swapping scheme mentioned.

He provides a useful analysis within his context.

Bitzer, D., and Skapendas, "The Design of an Economically Viable Large-scale Computer-based Education System," University of Illinois Computer-based Ed. Research Lab, CERL Report No. X-5, also a Report to the Commission on Instructional Technology, 1969.

The authors argue for economic viability of an instructional system. The estimate of ten man-years for the system development is reasonable, and the "plasma" terminal upon which all dreams rest is rapidly approaching commercial status.

Other aspects in the cost estimates raise questions. For instance, will authors adjust to writing computer instructional material? Scholarly books and some texts provide prestige and profit, and usually fulfill the "publish or perish" dictum. Although some time-sharing services do install applications programs and pay the author a use-rental, and at least one professional journal is reviewing computer-based learning exercises, the area of materials and authorship is weak component of the Illinois plan applied elsewhere.

Adams, E.N., "Technical Considerations in the Design of a CAI System," in the Proceedings of an NCET Seminar on Computers in Education held at Leeds, England, September, 1969.

A good tutorial for persons interested in instructional use of computers who are not well informed about hardware and system considerations, although a number of specialized terms are left undefined. The document would be a useful guide also if references were included for more detailed information about terminals and time sharing systems.

The author provides a useful organization and conceptualization of technical considerations (for those who already know the content), e.g., terminal and communication options; separation of procedure and content; isolation of control functions; generative techniques; and simulation.

The discussion of systems is weak, perhaps because software considerations are only half based in computer science and half in education. More work is needed to relate data about hardware, point by point, to the administrative, psychological and instructional considerations.

Breed, L.M., and Lathwell, R.H., "The Implementation of APL/360," in Melvin Klerer, Juris Reinfelds (eds.), Interactive Systems for Experimental Applied Mathematics, Academic Press, New York, 1968, pp. 390-399.

This implementation was done with both the APL characteristics and the idea of a dedicated system in mind. The result has:

a) A supervisor which allocates all system resources according to a single comprehensive strategy;

b) A system design influenced by an advance analysis of APL user programs (hopefully representative);

c) Reduced overhead in the language interpreter because of attention to detail (via specialized programming techniques).

APL is easily interpreted in source form. Thus there is no translation to a systactically rearranged internal form; only a lexical replacement is done on the input. Run-time analysis uses transition state diagrams, an efficient top-to-bottom method.

A number of storage management and swapping tips are included, as well as short discussions on error recovery and system self-monitoring. Indirectly it supports the advice that system building is not for novices (such as most CAI project directors are in computer science).

Engvold, K.J., and Hughes, J.L., "A Multi-function Display System for Processing and Teaching," IFIP Congress 69, Amsterdam: North-Holland.

A trimodal instructional system (author, student, or program) is proposed. The article describes an implementation of the arrangement for an IBM 360 Model 50 driving an IBM 2250 graphics terminal. Engvold's article is very similar to an earlier one (CACM, Vol. 10, No. 16, p. 339) describing a similar system using an IBM 7040. The 2250 is flexible and fun, but rather expensive and really more powerful than necessary. What use is 8K of independent storage unless the student is doing very, very complex engineering graphics? The display of Bitzer would suffice for any of the authors' demonstrations, and for most of what they propose.

Frye, Charles H., "CAI Languages: Capabilities and Applications," Datamation (Sept., 1968), Vol. 14, No. 9, pp. 34-37. Reprinted in Richard C. Atkinson and H.A. Wilson (eds.) Computer Assisted Instruction: A Book of Readings, Academic Press, 1969.

Frye classifies languages used for instruction as: 1) conventional compiler languages, 2) modified conventional languages, 3) interactive languages, and 4) special instructional author-languages.

Using these language categories the author considers: 1) user orientation, 2) lesson handling, 3) record handling, 4) conditional branching, 5) answer matching service routines, 6) calculation features, and 7) communication devices.

Some of the information is misleading and the general discussion is not supported by specifics but is nevertheless useful. Consideration of general-purpose along with special-purpose instructional languages is important. More could be made about some truly essential or primitive features found in many CAI languages.

Frye suggests that instructional author-languages arose because standard programming languages were too difficult to use and experienced programming help was too expensive. He should also recognize that although the prospective author need not learn as much to use a specific instructional language, he will not find it easy to deviate much from those programming styles and learning tasks which originally inspired the language.

Furthermore, new techniques for extending general-purpose languages (or generating special adaptations) will make relevant computer capabilities more accessible to non-specialists, among them the designer of computer-based lessons.

Glass, R.L., "An Elementary Discussion of Compiler/Interpreter Writing," Computing Surveys, (March 1969), Vol. 1, No. 1, pp. 55-77.

Elementary techniques are discussed for the translation of programming languages. Detailed discussion centers around a PL/1 interpreter which the author uses for an example.

A good annotated bibliography follows the article.

Johnson, B.F., "Design of an Operating System for the Control of Student Terminals in a Computer-based Instruction System," IFIP Congress '68, Amsterdam: North-Holland.

The RCA project described is quite straightforward technically. The use of re-entrant teaching programs is a good feature, and quite common for implementation of system programs; the teaching strategies are treated as system programs in the RCA system.

A background job stream should use residue CPU time and various other modes of computer use should be encouraged by additional facility. The system is rather narrowly conceived but well executed. It did have to be redone to get it running in the NYC schools the next year; current documentation is available from RCA, and user opinion from schools in NYC and Pontiac, Michigan.

Lyon, Gordon and Zinn, Karl L., "Some procedural language elements useful in an instructional environment," in the Proceedings of an NCET Seminar on Computers in Education held at Leeds, England, September 1969.

This paper attempts to attack the instructional language problem on the following fronts: A) Given reasonable demands, what programming language primitives adequately meet the requirements? B) How are the language features (or primitives) reflected in contemporary languages?

Suitable language primitives are discussed as parts of some general-purpose language. If the language will be used in interactive mode, some parts must be implemented as an interpreter to allow the very late binding times needed for flexibility.

If viewed as an attempt to cast light on procedural features in instructional computing, the paper may succeed. However, the hypothetical programming language described should not be taken very seriously. It is "cumbersome, vague, and patchwork; at best a sketch, certainly not a blueprint," as viewed by the authors.

Morton, M.S.S., and Zannetos, Z.S., "Efforts Toward an Associative Learning Instructional System," IFIP Congress '68, Amsterdam: North-Holland.

The authors propose a computer-driven interactive terminal linked to an associative memory with flexible search procedures to solve: a) lack of integrated instruction material; b) the inflexible pacing and sequencing of students. Postulated charactertistics of the system include semantic content association and learning (via pattern matching and adaptive characteristics).

The semantic memory has been programmed in such simplified form. An accounting course provided material formal enough so that keyword searching provided adequate "pattern matching". Pointers in the associative structures linked to other key words, thus providing rudimentary inferential powers.

The authors propose that semantic content, pattern recognition, adaptability (and, in addition, hardware flexibility) are the basic components of instructional teaching. An exhaustive testing of the prototype may provide some indication, perhaps encouraging an implementation which comes closer to testing the authors' hypothesis.

Tonge, F.M., "Design of a Programming Language and System for Computer Assisted Learning," IFIP Congress '68, Amsterdam; North Holland.

This is a well balanced summary of a system which became only partially operable at the University of California at Irvine. The view of early CAI languages as "five years behind the state of the programming art" rings true. The section on the requirements of the UC Irvine system is edifying, and some postscript on continuing problems would be useful.

Tonik, Albert B., "Development of Executive Routines, Both Hardware and Software," AFIPS, Fall Joint Computer Conference, Vo. 33, pp. 395-408, Thompson Books, Washington, D.C.

This tutorial expands from an elementary executive to a rather complex one. Topics include: simple executive, multiprogramming, paging, and multiprocessors.

In addition to the main article, there is a chronologically ordered bibliography with articles dating from 1948.

Zinn, Karl L., "A comparative study of languages for programming interactive use of computers in instruction," Final report under ONR contract N00014-68-C-0256 (Feb. 1969), EDUCOM, 100 Charles River Plaza, Bostom, Mass., 02114. 1969.

This report was preceded by the author's two other entries in this bibliography which are more available. It includes much of the detail promised in the other two: examples of actual code, summaries of languages, a discussion on interactive languages, a glossary of terms, aspects for a system taxonomy, and documentation guidelines.

More interpretable and directly useful work is in preparation in connection with Project CLUE.

Zinn, Karl L., "Programming conversational use of computers for instruction," Proceedings of the 1968 ACM National Conference, Brandon/Systems Press, Inc. Princeton, N.J., 08540, 1968.

From the 30 or so available languages for conversational instruction only 3 or 4 really different kinds have appeared. The author suggests: 1) successive-frame, 2) limited-context conversation, 3) presentation of a curriculum file by a standard procedure, and 4) data analysis and file editing.

Four types of users are considered: instructors, authors of instructional strategies, instructional researchers, and programmers and systems people.

Further discussion explores languages in a general-purpose, time-sharing environment. Extendibility is mentioned. The article concludes by comparing two low-cost extended languages (FOIL and FORFIT) and two standard languages for conversational instruction (COURSEWRITER and PLANIT).

Zinn, Karl L., "Languages for programming conversational use of computers in instruction," IFIP Congress 1968, Amsterdam: North Holland.

An outline of a comparative study of existing languages (then in progress) with tentative suggestions for improvements. Recommendations are derived from comments by authors of materials for various systems. The author also describes languages under development for a general-purpose system at the University of Michigan (IBM 360/67 using the Michigan Terminal System).

Zinn, Karl L., "Instructional programming languages: A five-year perspective," Educational Technology, March 1970.

Transcript of a presentation made at AERA in February 1969, this paper criticizes present languages and techniques for frame-oriented instructional programming and suggests new approaches to achieve effective and economical instruction by computer in the tutorial mode. The author recommends problem solving and procedure-writing uses for now because of economy and greater accessibility by individuals and smaller institutions. Some of the conclusions have been incorporated in the background statement prepared by the OECD-CERI meeting.

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